Nature
UNBOUND

the
impact of ecology
on Missouri and the World

MDC

DISCOVER
nature
SCHOOLS

TEACHER GUIDE

Forward

Nature Unbound, this instructional unit, has been developed to help high school students understand how all the pieces of their science knowledge are inter-related and to demonstrate how to connect those pieces to solve the puzzle of the natural world around them.

This teacher guide includes activities that have been designed to be incorporated into and to satisfy the ecology components of a high school biology course. Ecology Course Level Expectations (CLEs) are assessed in the end of course examination for biology, and this unit provides students with relevant content to address those CLEs.

Nature Unbound may also stand alone for high school elective courses in ecology, environmental science or agriculture education and resource management.

Science CLEs are aligned with objectives, content, essential activities and assessment items.

Before you begin, please
* Read through the information in the introductory materials.
* Have students read each chapter before beginning each lesson.
* Adapt activities to suit the needs of your students.

However you decide to incorporate the unit into your science curriculum, the overarching intent of *Nature Unbound* (and of all Discover Nature Schools units) is to lead student learning outdoors and into the natural world—the ultimate laboratory.

Acknowledgments

Table of Contents

Lesson 4: Interactions—Costs and Benefits of Survival 119

Lesson 5: Extinction—Causes and Consequences 137

Lesson 6: Exploring the Nature of Energy Flow 159

Lesson 7: The Cycling of Elements Through Ecosystems 177

Lesson 8: Diversity and Disturbance of Biological Communities 191

Lesson 9: Culminating Activity—Researching and Planning Like a Resource Manager 209

Appendices 213

Teacher Notes

Discover Nature Schools

Discover Nature Schools (DNS) is a science/conservation education program at its best. Instructional units comprise the backbone of the DNS program and include exciting and engaging hands-on activities designed to bring students in grades K-12 outdoors and closer to nature.

Each unit includes colorful and engaging student books as well as teacher guides with activities designed to meet Missouri Department of Elementary and Secondary Education (DESE) state standards. Grade Level Expectations (GLEs) for elementary and middle school and Course Level Expectations (CLEs) for high school are addressed. DESE at this time has not distinguished biology CLEs specific to ecology. Therefore, the Missouri Department of Conservation has reviewed and assigned those biology CLEs that address ecology for use in this curriculum. Use of science notebooks by students is an important and integrated component.

Lessons guide teachers toward utilizing immediate school grounds (schoolyard ecosystems) as important resources for student learning. At the heart of the DNS program is the belief that the more students equate the outdoors with learning, the more comfortable they become outdoors and the more in tune and familiar they become with outdoor environments. As students become more comfortable and familiar with learning and documenting outdoor experiences, the more they begin to think and act like observant scientists sensitive to and inquisitive about changes in outdoor environments. Many activities in each lesson are designed to be performed outdoors.

Student books and teacher guides (as well as training in their use) are available to all Missouri educators. However, teachers who enroll formally in the DNS program are eligible for additional resources including grant opportunities for field experiences, outdoor classrooms and classroom materials to support specific instructional units.

Timeline for DNS Units

Middle School—*Conserving Missouri's Aquatic Ecosystems*
Available since 2007

Elementary School—*Nature Unleashed: The Untamed World of Missouri Ponds, Forests and Prairies*
Available since 2009

High School—*Nature Unbound: The Impact of Ecology on Missouri and the World*
Pilot - fall of 2010
Available fall of 2011

Kindergarten–2nd grade—*See How the Turkey Grows*
Pilot - fall of 2011
Available fall of 2012

Early Childhood
Pilot - fall of 2012
Available fall of 2013

Unit Overview

Nature Unbound: The Impact of Ecology on Missouri and the World (Nature Unbound) is a unit designed to be taught at the high school level. Ecology CLEs are the primary targets.

Nature Unbound does not teach basic biology course concepts but rather builds on the foundation of prior knowledge achieved by students in biology.

Lessons with activities for teaching each chapter in the student book are provided (see "Lesson Components Overview" for more details) as well as alignment to the Missouri State Standards. An alignment piece in the form of a continuum chart is provided to reflect alignment of *Nature Unbound* to Grade Level Expectations (GLEs) in prior learning, Course Level Expectations (CLEs) in targeted learning; and Science College Board Standards for College Success in future learning.

Essential activities should be taught sequentially in order to guide students toward designing a field study or a multi-step plan—gathering, recording and organizing data while outdoors and presenting a report of findings to the class. The Lesson 9 activity incorporates this field study or plan as a culminating activity. This is intended to allow students the chance to demonstrate their ability to think and act like scientists and to provide a key assessment piece for the teacher.

Nature Unbound activities are designed to be adapted easily by teachers to meet student needs. Most activities in this unit are designed to get students outdoors and exploring, investigating and asking questions about immediate areas around their school. Science notebooks are integrated into each activity and can play a key role in student learning. By using science notebooks, students model the behavior and investigation methods of scientists. A variety of activities has been included to provide tools to meet diverse learning styles of students and to allow for teaching styles and preferences.

A detailed outline of answers to objectives is included with each lesson for teacher reference. Formative and summative assessments are also provided for each lesson.

A brief "misconception quiz" has been included and should be administered to students before beginning the unit to help identify and address any science concept misconceptions students may have.

Students should take the pre-test at the beginning and again as a post-test at the end of the unit. Pre- and post-test scores are important tools for assessment of student learning and for evaluation of the *Nature Unbound* unit.

Learning Outdoors

Most activities for *Nature Unbound* lessons are designed to be held outdoors. Tips for providing successful outdoor learning mirror tips for basic, traditional indoor classroom management and learning:

- Establish rules for outdoor experiences.
- Become familiar with the outdoor areas to be used for the unit's activities.
- Locate and identify for students any poison ivy, thorny brush, etc. to be avoided.
- Ensure that students are aware of their assignment(s) and time limit(s) as well as study/assignment locations, signals for gathering, signals for time, etc.
- Discuss the importance of being prepared for outdoor learning: weather-appropriate attire, insect repellent, sunscreen, etc.
- Provide field guides and/or encourage students to draw detailed pictures and write descriptions "to solve outdoor mysteries" when they return to the classroom.
- Embrace unexpected teachable moments that might "interrupt" an outdoor learning experience.
- Provide time for students to reflect on each outdoor learning experience.
- Share your reflections with your students.

Unit Time Frame

Nature Unbound unit (all lesson activities)—approximately 3 to 4 weeks excluding assessments.

"Estimated Time" section suggests how much time it may take to teach each lesson and activity. Actual time will be affected by the following factors:

- daily schedule of the school
- need for review of previous learning based on the extent of student prior knowledge
- need for reteaching based on the results of formative assessments
- additional resources/knowledge of teacher
- time allotted for group presentations based on class size
- time allotted for cooperative learning ativities
- number of activities given as homework rather than completed as class activities
- availability of resources for student use
- number and type of "Extension Activities" and "Optional Activities" used

Lesson Title	Estimated Time
Lesson 1: **What is Ecology?**	**Activities 1.1, 1.2, 1.3**—50 minutes
Lesson 2: **Reproduction and Adaptation**	**Activities 2.1, 2.2, 2.3**—50 minutes
Lesson 3: **Population Checks and Balances**	**Activities 3.1, 3.2, 3.3**—50 minutes
Lesson 4: **Interactions—Costs and Benefits of Survival**	**Activities 4.1, 4.2**—50 minutes
Lesson 5: **Extinction—Causes and Consequences**	**Activities 5.1, 5.2**—50 minutes
Lesson 6: **Exploring the Nature of Energy Flow**	**Activities 6.1, 6.2**—50 minutes
Lesson 7: **The Cycling of Elements Through Ecosystems**	**Activities 7.1, 7.2**—50 minutes
Lesson 8: **Diversity and Disturbance of Biological Communities**	**Activities 8.1, 8.2, 8.3**—50 minutes
Lesson 9: Culminating Activity— **Researching and Planning Like a Resource Manager**	Minimum of (2) 50-minute class periods and 1 day for a field experience

Lessons

A lesson is defined as a logical grouping of information to be taught. Individual lessons will most likely be taught over several days. A lesson in this teacher guide does not necessarily equate to a daily lesson plan. Lessons correspond to chapters in the student book. Lesson 1 in the teacher guide corresponds to Chapter 1 in the student book.

Lesson Components

Estimated Time—Estimated time for each lesson indicates the approximate time to teach the Essential Activities of the lesson. Estimated time for each activity **does not** include time for student reading of the chapter and may be adjusted for class discussions and outdoor research.

Science CLEs—Only CLEs specifically addressed in each lesson are listed. Any portion of a CLE not addressed will have a line drawn through it.

Vocabulary—Vocabulary listed in each lesson reflect terms bolded in the corresponding chapter in the student book. These are key terms that students must master to fully comprehend the concepts being addressed. These terms are listed in the CLEs and will be assessed. They are defined in the student book text and glossary.

Lesson Objectives—Objectives addressed in the lesson are listed.

Resource Management Objectives—Objectives addressed in the lesson are listed.

Essential Questions for the Lesson—Essential questions are provided to guide students toward field investigations that have the potential to provide rigorous and engaging inquiry experiences. Essential questions may be used to set the stage for the lesson. They may be listed on a bulletin board, blackboard, whiteboard, etc. and are intended to help students think and address questions and ideas as scientists.

Teacher Notes—This section provides information to help teachers prepare for the lesson. It may contain additional content information, notes or comments about the lesson, any necessary advanced preparation as well as suggested references for background information.

Outline of Answers to Objectives—Content addressed by each objective has been outlined and included in each lesson. Page numbers included at the end of each objective refer to the relevant pages in the student book.

Essential Activities—Most lessons have at least two Essential Activities. These activities address and help meet lesson objectives and CLEs listed for each activity.
    Essential Activities include:
- Estimated time
- Objectives
- Teacher preparation
- Materials
- Procedure
- Wrap up
- Assessment

Extension Activities—Extension activities are either optional portions of an Essential Activity or follow-up activities to an Essential Activity. Extension Activities enhance the Essential Activities but are not required to meet the lesson objectives.

Optional Activities—Optional activities do not necessarily enhance specific activities nor are they required to meet lesson objectives. They do provide opportunities for further study related to the lesson. They may also provide an alternative way to teach one of the essential activities. If there are no optional activities for the lesson, this section heading will not be listed.

Summary—This is the "Big Ideas" list provided at the beginning of the corresponding chapter in the student book.

End of Chapter Assessment—This section provides an opportunity for teachers to evaluate and adjust/revisit their instruction through assessment of student learning (i.e., what needs to be re-taught before moving on to the next lesson). Some or all of the items may be used in different ways depending on teacher preference and student needs. An answer key with possible points for each item is provided.

Examples of some ways to use an End of Chapter Assessment:

- Advanced Organizer—Students complete required items as they read the corresponding chapter. These are reviewed to determine student learning and understanding or are referenced during discussions and revised by students as needed.
- Cooperative Learning—Incorporate items into group discussions.
- Worksheet—Items used as in-class activity/activities or as homework when appropriate. Answer key may be used to grade responses.
- Quiz—All or part graded after completing all Essential Activities.

Student Science Notebooks

Science notebooks are an extremely useful tool for students and teachers alike. They promote good data collection and record-keeping habits and provide reference tools for students. For teachers, they provide ample opportunity for assessment of student work and data organization.

An excerpt from *Using Science Notebooks in Elementary Classrooms* by Michael P. Klentschy published in *NSTA Reports* (monthly newspaper of the National Science Teachers Association), September 2008, Volume 20, Number 1, has been reprinted and included below with permission of NSTA. This excerpt provides useful information on different approaches to and support for the use of science notebooks.

Klentschy (2008) states in the excerpt cited above that "scientists keep notebooks; students should do likewise. Scientists' notebooks include what worked and what did not work in the investigation. They sometimes learn much more from what did not work."

Activities in this teacher guide encourage students:

1. To develop their own methods of collecting, recording and presenting data from investigations and long-term observations
2. To share, compare and discuss their methods and findings with other students
3. To re-evaluate their methods, discuss whether or not their investigation was a "fair test" and discuss possible alternatives to their methods
4. To maintain permanent records of all their discussions, observations, data recording methods, etc.
5. To create testable questions, hypotheses and experiments or field research studies

In this way, students are provided "with the opportunity to use science notebooks in much the same way scientists do" and students begin to recognize science notebooks as useful resources for future studies whether the methods used were successful or not.

Science notebooks are important to use with most of the activities found in *Nature Unbound*. Students should record the basic information suggested in the science notebook headings on each outdoor (field) excursion. Abiotic factors such as weather and temperature will affect what they see. As students gather data throughout this unit, they should compare these field notes and draw correlations between abiotic and biotic factors. The data collection sheets supplied with some activities may be attached to the appropriate blank page in a science notebook.

Heading information may vary, but the following basic information should be included for each activity heading. Repetition of this process will reinforce good record-keeping and data collection techniques useful to students throughout their school experiences as well as their lives.

Science Notebook Headings

Title
Date
Time
Location
Air temperature (recorded outside)
Weather conditions* (recorded outside)
Rainfall

* Weather conditions include cloud cover, wind speed and direction, humidity, etc. Students may collect information via the Web (http://www.noaa.gov). Collection of this weather-related data over time provides students the opportunity to correlate weather and weather patterns to organisms and organism behavior. Students should write summaries of such correlations and draw conclusions. How does weather affect animal behavior? How does it affect migration? How are plants affected by the weather?

Klentschy, M.P., *Using Science Notebooks in Middle School Classrooms*, NSTA Press (Arlington, Virginia), 2010

Additional Resources

Britsch, Susan and Daniel P. Shepardson. "The Art of Reviewing Science Journals." *Science and Children*, Nov–Dec 2004. pp. 43–45
Campbell, Brian and Lori Fulton. *Science Notebook: Writing About Inquiry*. Portsmouth, NH: Heinemann. 2003
Campbell, Brian and Lori Fulton, "Student-Centered Notebooks." *Science and Children*, Nov-Dec 2004. pp. 26-29
Calhoun, Jeri and Ellen Mintz. "Project Notebook." *Science and Children*, Nov-Dec 2004. pp. 30-34
Leslie, Clare Walker and Charles E. Roth. *Nature Journaling*. Vermont: Storey Books. 1998
Moriarty, Robin, Jeff Winokur and Karen Worth. "Capitalizing on Literacy Connections." *Science and Children*, Feb 2004. pp. 35-39

Body of the Notebook

Many of the activities start with a question and/or ask the students to develop a question. What students record in their science notebooks may vary according to topic but should include:

- **Record of observations** including labeled sketches
- **Data collection**—Provided data sheets should be incorporated into science notebooks. Encourage students to create their own graphic organizers (data tables, classifying charts, claim and evidence charts, etc.) in their notebooks.
- **Conclusion and/or Summary**—Summarized information collected and answers to questions provided or questions created by students.
- **Reflection**—Reflections on the process, recorded and shared.
  Were there other ways to collect the data?
  Were there tools that might have been better to use?
  What other way(s) could the investigation or experiment have been conducted?
  What other questions could/should have been asked?
- **Page numbers**—Table of contents and page numbers (to allow reference to previous experiences)

National Science Teachers Association Article

Student science notebooks are advocated by researchers who believe that writing in science enhances student understanding of science content and process skills. Student science notebooks can be embedded into the science curriculum as a natural part of the goal to assist students in making evidence-based explanations of their science investigations.

The student science notebook is more than a record of data that students collect, facts they learn, and procedures they conduct. It is also a record of students' reflections, questions, predictions, claims linked to evidence, and conclusions, all structured by an investigation leading to an understanding of "big ideas," not just factoids in science. As such, a science notebook is a central place where language, data, and experience work together to form meaning for the student. This form of competence or expertise is developed through active construction of knowledge. Students need time and practice using science notebooks to attain expertise.

Student science notebooks, used well, become an embedded element in the curriculum and thus serve as a ready source of recorded data for both the student and the teacher. They become a direct measure of student understanding of the implemented curriculum and an important means for formative assessment. The science notebooks also reflect an accounting of the progression of an investigation as students formulate and record questions; make predictions; develop a plan of action; record observations, measurements, and data; link claims to evidence; and finally reflect on the investigation. They are the students' personal record that can be referred to and revised throughout an investigation or even an entire unit of study. The science notebooks also serve as the evidence used in group and class discussion.

There are many different approaches to having students create and utilize science notebooks: composition books, blank lab books, lined sheets of paper stapled together or loose-leaf binders.

In primary grades, class or group science notebooks may be created for a unit of study instead of individual student notebooks. Classroom teachers often form covers in the shape of the unit of study, such as a round cover if the students are studying the planets or the Moon. Students as early as kindergarten should be encouraged to keep a record of science investigations. Often these entries will come in the form of scribbles or drawings only decipherable to the student. These form the foundation for later work, when more specific criteria and writing prompts or sentence starters are more formally introduced. The main objective is for teachers to initially provide students with the opportunity to record their science investigation. ...

Scientists keep science notebooks; students should do likewise. Scientists' notebooks include what worked and what did not work in the investigation. They sometimes learn much more from what did not work. These notebooks include data, drawings, charts, and reflections, as well as new questions. Scientist entries are a record of what was learned at the time of the investigation and are not crossed out or erased when new discoveries take place. Newer ideas, thoughts, and reflections are added as new entries. Classroom teachers should adjust their teaching to provide students with the opportunity to use science notebooks in much the same way scientists do.

Citations [from full article]

Amaral, O., L. Garrison, and M. Klentschy. 2002. Helping English learners increase achievement through inquiry-based science instruction. *Bilingual Research Journal* 26 (2): 213–239.

Campbell, B. and L. Fulton. 2003. *Science notebooks*. Portsmouth, NH: Heinemann.

Klentschy, M., and E. Molina-de la Torre. 2004. *Students' science notebooks and the inquiry process. In Crossing borders in literacy and science instruction: Perspectives on theory and practice*, ed. W. Saul, 340–354. Newark, DE: International Reading Association.

Klentschy, M. P., *Using Science Notebooks in Elementary Classrooms*, NSTA Press (Arlington, Virginia), 2008

Rivard, L., and S. Straw. 2000. *The effect of talk and writing on learning science: An exploratory study.* Science Education 84 (5): 566–593.

Shepardson, D., and S. Britsch. 2001. *The role of children's journals in elementary school science activities.* Journal of Research in Science Teaching 38 (1): 43–69.

Field Investigations

Use of science notebooks and field investigation techniques by students are integrated components of the *Nature Unbound* unit. The following excerpt from *Field Investigations: Using Outdoor Environments to Foster Student Learning of Scientific Processes* developed for the Association of Fish and Wildlife Agencies' North American Conservation Education Strategy and developed by the Pacific Education Institute is included here to provide teachers with background information on the importance of field investigations and how it relates to student learning.

Field investigations help students become **systems thinkers**, learn the skills of scientific inquiry, and understand that science **doesn't only happen in a laboratory or classroom**. Outdoor experiences in natural settings increase students' problem solving abilities and motivation to learn in social studies, science, language arts and math.

When planning and conducting field investigations, students and scientists grapple with the difficulties of working in a natural system and at the same time develop an understanding of its complexities and subsystems. Systems-thinking involves thinking about relationships, rather than about individual objects. A system can be defined in a number of ways:

- An assemblage of inter-related parts or conditions through which matter, energy, and information flow.
- An organized group of related objects or components that form a whole.
- A collection of things and processes (and often people) that interact to perform some function. The scientific idea of a system implies detailed attention to inputs and outputs and interactions among the system components.

State and national science education standards encourage instruction that focuses on problem-solving and inquiry—activities which characterize the pursuits of scientists. In field investigations, students pose a research question then plan and conduct an investigation to answer that question. Students use evidence to support explanations and build models, as well as to pose new questions about the environment. Students learn that the scientific method is not a simple linear process and, most importantly, experience the difficulty of answering essential questions such as:

- What defines my environment?
- What are all the parts and interrelationships in this ecosystem?
- What is a healthy environment?
- What is humans' relationship to the environment?
- How has human behavior influenced our environment?
- How can our community sustain our environment?
- What is my role in the preservation and use of environmental resources?

Field investigations help students become informed citizen scientists who add knowledge to the community's understanding of an area in order to make issues of concern visible and share differing points of view about the preservation and use of community natural resources.

Classroom science often overemphasizes experimental investigation in which students actively manipulate variables and control conditions. In studying the natural world, it is difficult to actively manipulate variables and maintain "control" and "experimental" groups, so field investigation scientists look for descriptive, comparative, or correlative trends in naturally occurring events. Many field investigations begin with counts (gathering baseline data). Later, measurements are intentionally taken in different locations (Ex. urban and rural, or where some natural phenomenon has created different plot conditions), because scientists suspect they will find a difference. In contrast, in controlled experiments, scientists begin with a hypothesis about links between variables in a system. Variables of interest are identified, and a "fair test" is designed in which variables are

actively manipulated, controlled, and measured in an effort to gather evidence to support or refute a causal relationship.

For conceptual clarity, we have identified three types of field investigations—descriptive, comparative, and correlative.

Descriptive field investigations involve describing and/or quantifying parts of a natural system.	Comparative field investigations involve collecting data on different populations/organisms or under different conditions (Ex: times of year, locations) to make a comparison.	Correlative field investigations involve measuring or observing two variables and searching for a relationship.

Each type of field investigation is guided by different types of investigative questions. Descriptive studies can lead to comparative studies, which can lead to correlative studies. These three types of studies are often used in combination to study the natural world.

Ryken, A. E., Otto, P., Pritchard, K., & Owens, K. (2007). *Field Investigations: Using Outdoor Environments to Foster Student Learning of Scientific Processes.* Pacific Educational Institute.

Reprinted with permission from Dr. Margaret Tudor, Co-Executive Director of the Pacific Educational Institute, Market Place Office Building, 724 Columbia St. NW, Suite 250, Olympia, WA 98501 (mtudor@wfpa.org).

Collection of Organisms
Not all organisms need to be captured. Many organisms, including insects, may be identified by recording observations in the field and using field guides, Internet, etc. in the classroom. If it is necessary to capture an organism for identification and/or observation, release it where it was captured. Obtain permission to collect specimens whether collecting them from the schoolyard ecosystem or other sites. Collection permits may be required. Some areas, including state conservation areas, require a wildlife collector's permit even if captured specimens are to be released unharmed.

Assessment Strategies
Several different assessment strategies are available at the end of each lesson to help determine whether students have grasped and fully understand the concepts addressed in the objectives. Both formative and summative assessment items are provided.

Alignment to Missouri Standards

Missouri Science Concepts (Strands 1-6) addressed:

ME.1.I.a Compare the mass of the reactants to the mass of the products in a chemical reaction ofphysical change (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, decomposition and synthesis reactions involved in a food web) as support for the Law of Conservation of Mass

ME.2.A Forms of energy have a source, a means of transfer (work and heat), and a receiver

ME.2.F.a ~~Classify the different ways to store energy (i.e., chemical, nuclear, thermal, mechanical, electromagnetic) and~~ describe the transfer of energy as it changes from kinetic to potential, while the total amount of energy remains constant, within a system (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, food web)

LO.3.A.a Distinguish between asexual (i.e., binary fission, budding, ~~cloning~~) and sexual reproduction

LO.3.D There is heritable variation within every species of organism

LO.3.D.a Describe the advantages and disadvantages of asexual and sexual reproduction with regard to variation within a population

LO.3.D.c Recognize that new heritable characteristics can only result from new combinations of existing genes or from mutations of genes in an organism's sex cells

EC.1.A All populations living together within a community interact with one another and with their environment in order to survive and maintain a balanced ecosystem

EC.1.A.a Explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (i.e., mutualism, commensalism, parasitism)

EC.1.A.b Explain how cooperative (e.g., symbiotic) and competitive (e.g., predator/prey) relationships help maintain balance within an ecosystem

EC.1.A.c Explain why no two species can occupy the same niche in a community (The functional role of a species is not limited to its placement along a food pyramid; it also includes the interactions of a species with other organisms while obtaining food. For example, the methods used to tolerate the physical factors of its environment, such as climate, water, nutrients, soils, and parasites, are all part of its functional role. In other words, the ecological niche of an organism is its natural history: all the interactions and interrelationships of the species with other organisms and the environment.)

EC.1.B.a Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem

EC.1.B.b Predict how populations within an ecosystem may change in number and/or structure in response to hypothesized changes in biotic and/or abiotic factors

EC.1.C.a Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible adverse effects of human interactions with that ecosystem (e.g., destruction caused by direct harvesting, pollution, atmospheric changes)

EC.1.C.b   Predict and explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents)

EC.1.D.a   Predict the impact (beneficial or harmful) a natural or human caused environmental event (e.g., forest fire, flood, ~~volcanic eruption, avalanche~~, acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on the diversity of different species in an ecosystem

EC.1.D.b   Describe possible causes of extinction of a population

EC.2.A   As energy flows through the ecosystem, all organisms capture a portion of that energy and transform it to a form they can use

EC.2.A.a   Illustrate and describe the flow of energy within a food web

EC.2.A.b   Explain why there are generally more producers than consumers in an energy pyramid

EC.2.A.c   Predict how the use and flow of energy will be altered due to changes in a food web

EC.2.B.a   Explain the processes involved in the recycling of nitrogen, oxygen, and carbon through an ecosystem

EC.2.B.b   Explain the importance of the recycling of nitrogen, oxygen, and carbon within an ecosystem

EC.3.C   Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem

EC.3.C.a   Identify examples of adaptations that may have resulted from variations favored by natural selection (~~e.g., long-necked giraffes, long-eared jack rabbits~~) and describe how that variation may have provided populations an advantage for survival

EC.3.C.b   Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance)

EC.3.C.c   Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection

EC.3.C.d   Given a scenario describing an environmental change, hypothesize why a given species was unable to survive

Alignment to Missouri Show-Me Goals and Performance Standards:

1.1   Develop questions and ideas to initiate and refine research
(Activites: all)

1.2   Conduct research to answer questions and evaluate information and ideas
(Activities: 5.2, 8.2)

1.3   Design and conduct field and laboratory investigations to study nature and society
(Activities: 1.1, 1.3, 7.2, 8.3, 9)

1.5   Comprehend and evaluate written, visual, and oral presentations and works
(Activities: 4.1)

1.6   Discover and evaluate patterns and relationships in information, ideas and structures
(Activities: 1.2, 2.1)

1.8   Organize data, information and ideas into useful forms (including charts, graphs, outlines) for analysis and presentation
(Activities: 2.3, 6.1, 6.2)

1.10   Apply acquired information, ideas and skills to different contexts as students, workers, citizens and consumers
(Activities: 2.2, 3.1, 3.2, 3.3, 4.2, 7.1)

3.2   Develop and apply strategies based on ways others have prevented or solved problems
(Activities: 5.1)

3.5   Reason inductively from a set of specific facts and deductively from general premises
(Activities: 8.1)

Alignment to Missouri Show-Me Goals and Content Standards:

SC1   Properties and principles of matter and energy
(Lessons: 6, 7)

SC3   Characteristics and interactions of living organisms
(Lessons: 2)

SC4   Changes in ecosystems and interactions of organisms with their environments
(Lessons: 1, 2, 3, 4, 5, 6, 7, 8, 9)

SC7   Processes of scientific inquiry (such as formulating and testing hypotheses)
(Lessons: 1, 2, 3, 4, 5, 6, 7, 8, 9)

SC8   Impact of science, technology and human activity on resources and the environment
(Lessons: 1)

Alignment to Mathematics CLEs:

N.1.B.A.2 Use real numbers and various models, drawings, etc. to solve problems

N.3.E.A.2 Solve problems involving proportions

A.2.C.A.2 Use and solve equivalent forms of equations (linear, absolute value and quadratic) and inequalities

Alignment to Communication Arts CLEs:

R3C2 Use details from informational and persuasive text(s) to
   a. analyze and evaluate the organizational patterns
   b. identify and analyze faulty reasoning and unfounded inferences
   c. evaluate proposed solutions
   d. evaluate for accuracy and adequacy of evidence
   e. evaluate effect of tone on the overall meaning of work
   f. analyze and evaluate point of view
   g. analyze and evaluate author's viewpoint/perspective
   h. demonstrate comprehension skills previously introduced

R3D2 Read and apply multi-step directions to perform complex procedures and/or tasks

W2B2 Compose text with
   a. strong controlling idea
   b. relevant specific details
   c. complex ideas
   d. freshness of thought

W3A2 Compose a variety of texts
   a. using narrative, descriptive expository, and/or persuasive features.
   b. in various formats, including workplace communication
   c. including summary
   d. including literary analysis
   e. including reflective writing

LS2A In discussions and presentations,
   • create concise presentations on a variety of topics
   • incorporate appropriate media or technology
   • respond to feedback
   • defend ideas
   • demonstrate poise and self-control

LS2B Give clear and concise multi-step oral directions to perform complex procedures and/or tasks

IL1A Develop an appropriate research plan to guide investigation and research of focus questions

IL1C Record relevant information from multiple primary and secondary sources using a self-selected note-taking or organizational strategy

Science Course Level Expectations Alignment

In this unit, students develop the Science Course Level Expectations (CLEs) listed in the Targeted Learning column below. While supporting students in the development of these skills, teachers should consider students' prior learning and keep in mind their future learning. The CLEs listed in the Targeted Learning column may be addressed in more than one lesson. In the Lesson column, the lesson number(s) are listed followed by which CLE or which portion of a CLE is covered by the lesson. The Depth of Knowledge (DOK) coding indicated in the row directly below the CLE is from the Missouri Department of Elementary and Secondary Education (DESE).

The CLE number coding is in the format used by DESE. The first two letters refer to the strand. (ME=Matter and Energy, LO=Living Organisms, EC=Ecology, IN=Inquiry, ST=Impact of Science, Technology and Human Activity). The first number refers to the "Big Idea" number under the strand. Next, the single uppercase letter refers to the "Concept" under the Big Idea. The lower case letter refers to the specific CLE. See example below:

LO.3.A.a=LO (Living Organisms). 3. There is a genetic basis for the transfer of biological characteristics from one generation to the next through reproductive processes. A. Reproduction can occur asexually or sexually. a. Distinguish between asexual (i.e., binary fission, budding, cloning) and sexual reproduction.

The first column lists the CLEs that align to the lessons and the assessments for each lesson. Not all the CLEs in the first column are used in the activities but all are found in the reading material for the lesson and/or in the Assessment.

The second column aligns the pre/post test and summative assessments at the end of each lesson. CR2 DOK3 1.1 CR=Constructive Response (Other question types would include: MC=Multiple Choice; PE=Performance Event; T/F=True and False; Match=Matching); 2=question number in assessment; DOK=Depth of Knowledge level of question; Goals and Standards "Blue Placemat" *ex.* 1.1=Develop questions and ideas to initiate and refine research.

Future learning has been extracted from "Science College Board Standards for College Success." The "Science College Board of Standards" document can be found on the following website: http://professionals.collegeboard.com/profdownload/cbscs-science-standards-2009.pdf. LS.1.3. states an objective: LS=Life Science; 1.3=Objective code=Objective: 1=Genetic Variation Within Populations .3=Students understand that genetic variation within a population is essential for natural selection. Mutations, as well as random assortment of existing genes, can produce genetic variation in a population. Under the objective you will find the (9-12) grade level and a blue box of statements. The blue box is bulleted. These statements are more precise than the objectives and match specific CLEs. The exact bullet that is in alignment is indicated. This document consists of knowledge from High School Advanced Placement Classes that students need before they enter college.

Lesson 1	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.A	CR2 DOK2 1.10 MC7 DOK3 1.6	EC.1.B.6.a DOK2	EC.1.A All populations living together within a community interact with one another and with their environment in order to survive and maintain a balanced ecosystem.	LS.1.3 (9-12) Blue box bullet 1 Natural selection can occur only if there is variation in the genetic information between organisms of the same species in a population and variation in the expression of that genetic information as a trait. Genetic variation within a population influences the likelihood that a population will survive and produce offspring.

Lesson 1	Prior Learning	Targeted Learning	Future Learning	Assessment
EC.1.B.a	EC.1.A.6.a DOK2	EC.1.B.a Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem. DOK2	LS.3.3 (9-12) Blue box bullet 1 The number of organisms in ecosystems fluctuates over time as a result of mechanisms such as migration, birth and death. These fluctuations in the size of populations offset the stability of ecosystems in terms of habitat and resource availability.	Pre/Post test: MC3 DOK2 1.10
EC.1.D.a		EC.1.D.a Predict the impact (beneficial or harmful) a natural environmental event (e.g., forest fire, flood, volcanic eruption, avalanche) or human caused change (e.g., acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on the diversity of different species in an ecosystem.		
IN.1.A.a		IN.1.A.a Formulate testable questions and hypotheses. DOK 3		CR3 DOK3 1.3
IN.1.A.c		IN.1.A.c Design and conduct a valid experiment.		CR6 DOK2 1.6
IN.1.B.a		IN.1.B.a Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2		CR4 DOK2 1.3
IN.1.C.a		IN.1.C.a Use quantitative and qualitative data as support for reasonable explanations (conclusions). DOK3		MC5 DOK3 1.6
ST.2.B		ST.2.B Scientific theories are developed based on the body of knowledge that exists at any particular time and must be rigorously questioned and tested for validity.		Pre/Post test: MC2 DOK1 1.10 CR8 DOK2 1.6
ST.3.A		ST.3.A People, alone or in groups, are always making discoveries about nature and inventing new ways to solve problems and get work done.		MC9 DOK1 1.10

Lesson 2	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.B.a	**Pre/Post Test:** **MC3 DOK2 1.10**		**EC.1.B.a** Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem. DOK2	
EC.1.C.b		**EC.1.D.6.a DOK2**	**EC.1.C.b** Predict and explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents). DOK2	**LS.1.2 (9-12) Blue box bullet 4** When environmental change—naturally occurring or human induced—happens, extinction can occur. Species become extinct because they cannot survive and reproduce in their environments. If members cannot adjust—because change in the environment is too fast or too drastic—they die or become unable to reproduce, thus negating opportunity for evolution.
EC.3.B.b	**MC9 DOK1 1.10**	**LO.1.A.6.a DOK2**	**EC.3.B.b** Explain the importance of reproduction to the survival of a species (i.e., the failure of a species to reproduce will lead to extinction of that species). DOK2	**LS1.2 (9-12) Blue box bullet 2** Over time, the differential survival and reproduction of organisms with a population that have an advantageous heritable trait lead to an increase in proportion of individuals in future generations that have the trait and a decrease in the proportion of individuals that do not.
EC.3.C	**CR6 DOK1 1.10**		**EC.3.C** Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	**LS.1.3** Genetic variation within populations: Students understand that genetic variation within a population is essential for natural selection. Mutations, as well as random assortment of existing genes, can produce genetic variation in a population.
EC.3.C.a	**MC12 DOK1 1.8**	**EC.3.C.C.6.a-b DOKa2-b3**	**EC.3.C.a** Identify examples of adaptations that may have resulted from variations favored by natural selection (e.g., long-necked giraffes, long-eared jack rabbits) and describe how that variation may have provided populations an advantage for survival. DOK2	**LS.1.3 (9-12) Blue box bullet 1** Natural selection can occur only if there is variation in the genetic information between organisms of the same species in a population and variation in the expression of that genetic information as a trait. Genetic variation within a population influences the likelihood that a population will survive and produce offspring.

Lesson 2	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.3.C.b		**EC.3.C.6.b DOK3**	**EC.3.C.b** Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance). DOK2	**LS.1.3 (9-12) Blue box bullet 1** Natural selection can occur only if there is variation in the genetic information between organisms of the same species in a population and variation in the expression of that genetic information as a trait. Genetic variation within a population influences the likelihood that a population will survive and produce offspring.
EC.3.C.c		**EC.1.D.6.a DOK2**	**EC.3.C.c** Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection. DOK2	**LS.1.2 (9-12) Blue box bullet 3** Changes in the **abiotic** environment, including climatic and geological processes, have contributed to the decline of some species and expansion of other species.
EC.3.C.d	**CR7 DOK1 1.10** **CR8 DOK1 1.10**		**EC.3.C.d** Given a scenario describing an environmental change, hypothesize why a given species was unable to survive. DOK2	
LO.3.A.a	**Pre/Post test:** **MC4 DOK1 1.10**	**LO.3.A.8.a-b** **DOKa2-b1**	**LO.3.A.a** Distinguish between asexual (i.e., binary fission, budding, cloning) and sexual reproduction. DOK1	
LO.3.D	**CR3 DOK2 1.8**	**LO.3.D.8.a DOK1**	**LO.3.D** There is heritable variation within every species of organism.	**LS.1.3 (9-12) Blue box bullet 1** Natural selection can occur only if there is variation in the genetic information between organisms of the same species in a population and variation in the expression of that genetic information as a trait. Genetic variation within a population influences the likelihood that a population will survive and produce offspring.
LO.3.D.a	**Pre/Post test:** **MC5 DOK1 1.10** **CR1 DOK1 1.10** **CR2 DOK1 1.10** **CR5 DOK2 3.5** **MC10 DOK1 1.10**	**LO.3.A.8.a DOK2**	**LO.3.D.a** Describe the advantages and disadvantages of asexual and sexual reproduction with regard to variation within a population. DOK2	

Lesson 2	Assessment	Prior Learning	Targeted Learning	Future Learning
LO.3.D.c	CR4 DOK3 3.5	LO.3.D.8.b DOK1	**LO.3.D.c** Recognize that new heritable characteristics can only result from new combinations of existing genes or from mutations of genes in an organism's sex cells.	
IN.1.A.a			**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	
IN.1.B.a			**IN.1.B.a** Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2	

Lesson 3	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.A	**Pre/Post test:** MC6 DOK1 1.10		**EC.1.A** All populations living together within a community interact with one another and with their environment in order to survive and maintain a balanced ecosystem. DOK1	
EC.1.B.a	CR1 DOK2 1.10	EC.1.A.6.a DOKa2	**EC.1.B.a** Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem. DOK2	**LS.3.3 (9-12) Blue box bullet 1** The number of organisms in ecosystems fluctuates over time as a result of mechanisms such as migration, birth and death. These fluctuations in the size of populations offset the stability of ecosystems in terms of habitat and resource availability.
EC.3.C	CR7 DOK1 1.6		**EC.3.C** Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	**LS.1.3 Genetic variation within populations:** Students understand that genetic variation within a population is essential for natural selection. Mutations, as well as random assortment of existing genes, can produce genetic variation in a population.

Lesson 3	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.3.C.b		EC.3.C.6.b DOK3	**EC.3.C.b** Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance). DOK2	**LS. 1.3 (9-12) Blue box bullet 1** Natural selection can occur only if there is variation in the genetic information between organisms of the same species in a population and variation in the expression of that genetic information as a trait. Genetic variation within a population influences the likelihood that a population will survive and produce offspring.
EC.3.C.c	MC9 DOK1 1.6	EC.1.D.6.b DOK3	**EC.3.C.c** Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection. DOK2	**LS.1.2 (9-12) Blue box bullet 3** Changes in the **abiotic** environment, including climatic and geological processes, have contributed to the decline of some species and expansion of other species.
IN.1.A.a	CR5 DOK3 1.1		**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	
IN.1.A.b			**IN.1.A.b** Analyzing an experiment, identify the components (i.e., independent variable, dependent variables, control of constants, multiple trials) and explain their importance to the design of a valid experiment. DOK3	
IN.1.A.c	CR6 DOK2 1.10		**IN.1.A.c** Design and conduct a valid experiment. DOK4	
IN.1.B.a	MC2 DOK1 1.10		**IN.1.B.a** Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2	
IN.1.C.a			**IN.1.C.a** Use quantitative and qualitative data as support for reasonable explanations (conclusions). DOK3	

Lesson 3	Assessment	Prior Learning	Targeted Learning	Future Learning
IN.1.C.b	CR8 DOK1 1.10		IN.1.C.b Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable). DOK3	

Lesson 4	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.A.a	CR1 DOK1 1.8 MC10 DOK2 1.10	EC.1.B.6.a DOK2	EC.1.A.a Explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (i.e., mutualism, commensalism, parasitism). DOK1	LS.3.2 Blue box bullet 2 The relationships (e.g., mutualism, commensalism, parasitism, predator-prey, herbivore-autotroph) within an ecosystem vary. Some organisms depend so much on a particular organism for food and shelter that they cannot survive without this other organism.
EC.1.A.b	CR2 DOK1 1.10 CR3 DOK1 1.10 CR4 DOK1 1.10 MC9 DOK1 1.10	EC.2.A.6.b DOK2	EC.1.A.b Explain how cooperative (e.g., symbiotic) and competitive (e.g., predator/prey) relationships help maintain balance within an ecosystem. DOK2	LS.3.2 Blue box bullet 3 There are limits to the number and types of organisms and populations an ecosystem can support (carrying capacity), depending in part on how the particular organisms involved interact with each other. These limits are determined by factors such as disease, predation, competition, and availability of biological (biotic) resources and physical (abiotic factors.

Lesson 4	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.A.c	**Pre/Post test:** MC9 DOK1 1.10 CR5 DOK1 1.10 CR11 DOK1 1.10	**EC.1.B.6.c DOK3**	**EC.1.A.c** Explain why no two species can occupy the same niche in a community. (The functional role of a species is not limited to its placement along a food pyramid; it also includes the interactions of a species with other organisms while obtaining food. For example, the methods used to tolerate the physical factors of its environment, such as climate, water, nutrients, soils, and parasites, are all part of its functional role. In other words, the ecological niche of an organism is its natural history: all the interactions and interrelationships of the species with other organisms and the environment). DOK2	
EC.1.B.a	**Pre/Post test:** MC7 DOK1 1.10		**EC.1.B.a** Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem. DOK2	
EC.3.C.a	CR6 DOK2 1.10 CR7 DOK1 1.10	**EC.1.D.6.c DOK3**	**EC.3.C.a** Identify examples of adaptations that may have resulted from variations favored by natural selection (e.g., long-necked giraffes, long-eared jack rabbits) and describe how that variation may have provided populations an advantage for survival. DOK2	**LS.1.3 (9-12) Blue box bullet 1** Natural selection can occur only if there is variation in the genetic information between organisms of the same species in a population and variation in the expression of that genetic information as a trait. Genetic variation within a population influences the likelihood that a population will survive and produce offspring.
IN.1.A.a	**Pre/Post test:** MC8 DOK1 1.10 CR12 DOK3 1.3		**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	

Lesson 4	Assessment	Prior Learning	Targeted Learning	Future Learning
IN.1.B.a	CR13 DOK3 1.3		**IN.1.B.a** Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2	**LS.1.2 Blue box bullet 3** Changes in the abiotic environment, including climatic and geological processes, have contributed to the decline of some species and expansion of other species.
IN.1.B.e			**IN.1.B.e** Calculate the range, average/ mean, percent, and ratios for sets of data. DOK1	
IN.1.B.f			**IN.1.B.f** Recognize observation is biased by the experiences and knowledge of the observer (e.g., strong beliefs about what should happen in particular circumstances can prevent the detection of other results). DOK2	
IN.1.C.a			**IN.1.C.a** Use quantitative and qualitative data as support for reasonable explanations (conclusions). DOK3	
IN.1.C.b			**IN.1.C.b** Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable). DOK3	

Lesson 5	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.A.a		**EC.1.B.6.a DOK2**	**EC.1.A.a** Explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (i.e., mutualism, commensalism, parasitism). DOK1	

Lesson 5	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.A.c	**CR5 DOK2 1.10**	**EC.1.B.6.a-c DOKa2, b2, c3**	**EC.1.A.c** Explain why no two species can occupy the same niche in a community. DOK 2 (The functional role of a species is not limited to its placement along a food pyramid; it also includes the interactions of a species with other organisms while obtaining food. For example, the methods used to tolerate the physical factors of its environment, such as climate, water, nutrients, soils, and parasites are all part of its functional role. In other words, the ecological niche of an organism is its natural history: <u>All the interactions and interrelationships of the species with other organisms and the environment).</u>	
EC.1.B.b	**Pre/Post test: MC10 DOK1 1.10**		**EC.1.B.b** Predict how populations within an ecosystem may change in number and/or structure in response to hypothesized changes in biotic and/or abiotic factors	
EC.1.C.a	**MC7 DOK1 1.10**	**EC.1.D.6.c DOK3**	**EC.1.C.a** Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible adverse effects of human interactions with that ecosystem (e.g., destruction caused by direct harvesting, pollution, atmospheric changes). DOK3	
EC.1.C.b	**MC2 DOK1 1.10**	**EC.1.D.6.a DOK2**	**EC.1.C.b** Predict and explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents). DOK2	**LS.1.2 (9-12) Blue box bullet 4** When environmental change—naturally occurring or human induced –happens, extinction can occur. Species become extinct because they cannot survive and reproduce in their environments. If members cannot adjust—because change in the environment is too fast or too drastic—they die or become unable to reproduce, thus negating opportunity for evolution.

Lesson 5	Prior Learning	Assessment	Targeted Learning	Future Learning
EC.1.D.a	EC.1.D.6.a-b DOKa2, b3	**Pre/Post test:** MC12 DOK1 1.10 CR3 DOK1 1.6 CR4 DOK1 1.10 CR6 DOK1 1.10 MC8 DOK1 1.10	**EC.1.D.a** Predict the impact (beneficial or harmful) a natural or human caused environmental event(e.g., forest fire, flood, volcanic eruption, avalanche, acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on the diversity of different species in an ecosystem. DOK2	**LS.1.2 (9-12) Blue box bullet 4** When environmental change—naturally occurring or human induced—happens, extinction can occur. Species become extinct because they cannot survive and reproduce in their environments. If members cannot adjust—because change in the environment is too fast or too drastic—they die or become unable to reproduce, thus negating opportunity for evolution.
EC.1.D.b		**Pre/Post test:** MC11 DOK1 1.10	**EC.1.D.b** Describe possible causes of extinction of a population. DOK1	**LS.1.2 (9-12) Blue box bullet 2** Over time, the differential survival and reproduction of organisms within a population that have an advantageous heritable trait lead to an increase in the proportion of individuals in future generations that have the trait and a decrease in the proportion of individuals that do not.
EC.3.B.b	LO.1.A.6.a DOK2	**Pre/Post test:** MC1 DOK1 1.6	**EC.3.B.b** Explain the importance of reproduction to the survival of a species (i.e., the failure of a species to reproduce will lead to extinction of that species). DOK2	**LS1.2 (9-12) Blue box bullet 2** Over time, the differential survival and reproduction of organisms with a population that have an advantageous heritable trait lead to an increase in proportion of individuals in future generations that have the trait and a decrease in the proportion of individuals that do not.
EC.3.C		**Pre/Post test:** MC2 DOK1 1.10	**EC.3.C** Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	**LS1.1.3** Genetic variation within populations: Students understand that genetic variation within a population is essential for natural selection. Mutations, as well as random assortment of existing genes, can produce genetic variation in a population.
EC.3.C.d			**EC.3.C.d** Given a scenario describing an environmental change hypothesize why a given species was unable to survive. DOK2	
IN.1.A.a		CR/PE9 DOK3 1.3	**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	

Lesson 5	Assessment	Prior Learning	Targeted Learning	Future Learning
IN.1.A.b			**IN.1.A.b** Analyzing an experiment, identify the components (i.e., independent variable, dependent variables, control of constants, multiple trials) and explain their importance to the design of a valid experiment. DOK3	
IN.1.A.c			**IN.1.A.c** Design and conduct a valid experiment. DOK4	
IN.1.A.d			**IN.1.A.d** Recognize it is not always possible, for practical or ethical reasons, to control some conditions (e.g. when sampling or testing humans, when observing animal behaviors in nature). DOK2	
IN.1.B.c			**IN.1.B.c** Determine the appropriate tools and techniques to collect, analyze, and interpret data. DOK2	
IN.1.C.a			**IN.1.C.a** Use quantitative and qualitative data as support for reasonable explanations (conclusions). DOK3	
IN.1.C.b			**IN.1.C.b** Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable). DOK3	

Lesson 5	Prior Learning	Assessment	Targeted Learning	Future Learning
IN.1.D.a			IN.1.D.a Communicate the procedures and results of investigations and explanations through: • Oral presentations • Drawings and maps • Data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities) • Graphs (bar, single and multiple line) • Equations and writings DOK3	

Lesson 6	Prior Learning	Assessment	Targeted Learning	Future Learning
ME.1.I.a	ME.1.I.8.c DOK2	MC2 DOK1 1.10	ME.1.I.a Compare the mass of the reactants to the mass of the products in a chemical reaction or physical change (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, decomposition and synthesis reactions involved in a food web) as support for the Law of Conservation of Mass.	
ME.2.A		MC1 DOK1 1.10	ME.2.A. Forms of energy have a source, a means of transfer (work and heat), and a receiver.	
ME.2.F.a	ME.2.F.7.c DOK1		ME.2.F.a Classify the different ways to store energy (i.e., chemical, nuclear, thermal, mechanical, electromagnetic) and describe the transfer of energy as it changes from kinetic to potential, while the total amount of energy remains constant, within a system (i.e., biochemical, oxygen cycle, nitrogen cycle, food web). DOK2	

Lesson 6	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.2.A	CR4 DOK1 1.10	EC.2.A.6.a	EC.2.A As energy flows through the ecosystem, all organisms capture a portion of that energy and transform it to a form they can use.	LS.4.2 (9-12) Blue box bullet 1 Life processes involve a complex sequence of chemical reactions in which chemical energy is transferred from one system of interacting molecules to another. Some of the energy in these reactions is transferred to the environment as thermal energy (heat).
EC.2.A.a	Pre/Post test: CR5 DOK1 1.10 T/F12 DOK1 1.10 MC13 DOK1 1.10	EC.2.A.6.a DOK3	EC.2.A.a Illustrate and describe the flow of energy within a food web.	
EC.2.A.b	MC11 DOK1 1.10		EC.2.A.b Explain why there are generally more producers than consumers in an energy pyramid. DOK2	LS.3.2 Blue box bullet 3 There are limits to the number and types of organisms and populations an ecosystem can support (carrying capacity), depending in part on how the particular organisms involved interact with each other. These limits are determined by factors such as disease, predation, competition, and availability of biological (biotic) resources and physical (abiotic factors).
EC.2.A.c	Pre/Post test: MC14 DOK2 1.10		EC.2.A.c Predict how the use and flow of energy will be altered due to changes in a food web. DOK2	
EC.2.B.b	CR3 DOK2 1.10	EC.2.B.8.a DOK1	EC.2.B.b Explain the importance of the recycling of nitrogen, oxygen, and carbon within an ecosystem. DOK1	ES.4.2(9-12) The carbon cycle is intimately related to climate change through the processes that capture and release carbon dioxide and methane gases into the atmosphere. It is also related to the cycling of other important elements for living organisms, including nitrogen and phosphorus.
EC.3.C			EC.3.C Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	LS.1.3 Genetic variation within populations: Students understand that genetic variation within a population is essential for natural selection. Mutations, as well as random assortment of existing genes, can produce genetic variation in a population.

Lesson 6	Assessment	Prior Learning	Targeted Learning	Future Learning
IN.1.A.a	CR6 DOK3 1.3 CR7 DOK2 1.8		**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	
IN.1.D.a			**IN.1.D.a** Communicate the procedures and results of investigations and explanations through: • Oral presentations • Drawings and maps • Data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities) • Graphs (bar, single and multiple line) • Equations and writings DOK3	

Lesson 7	Assessment	Prior Learning	Targeted Learning	Future Learning
ME.1.I.a		**ME.1.I.8.c DOK2**	**ME.1.I.a** Compare the mass of the reactants to the mass of the products in a chemical reaction or physical change (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, decomposition and synthesis reactions involved in a food web) as support for the Law of Conservation of Mass.	
EC.2.B.a	**Pre/Post test:** **Match15-18** **DOK1 1.10** **Match5-12** **DOK1 1.10**	**EC.2.B.8.a DOK1**	**EC.2.B.a** Explain the processes involved in the recycling of nitrogen, oxygen, and carbon through an ecosystem. DOK2	
EC.2.B.b	**CR2 DOK1 1.10** **CR15 DOK1 1.10**	**EC.2.B.8.a-b** **DOKa1-b1**	**EC.2.B.b** Explain the importance of the recycling of nitrogen, oxygen, and carbon within an ecosystem. DOK1	

Lesson 7	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.3.C			**EC.3.C** Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	**LS.1.3** Genetic variation within populations: Students understand that genetic variation within a population is essential for natural selection. Mutations, as well as random assortment of existing genes, can produce genetic variation in a population.
EC.3.C.c	**CR14 DOK2 1.10** **CR17 DOK2 1.10**	**EC.1.D.6.b DOK3**	**EC.3.C.c** Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection. DOK2	
EC.3.C.d	**CR13 DOK1 1.10** **CR16 DOK2/3 1.3**		**EC.3.C.d** Given a scenario describing an environmental change, hypothesize why a given species was unable to survive. DOK2	
IN.1.A.a			**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	
IN.1.A.b			**IN.1.A.b** Analyzing an experiment, identify the components (i.e., independent variable, dependent variable, control of constants, multiple trials) and explain their importance to the design of a valid experiment. DOK3	
IN.1.A.c			**IN.1.A.c** Design and conduct a valid experiment. DOK4	
IN.1.B.a			**IN.1.B.a** Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2	

Lesson 7	Assessment	Prior Learning	Targeted Learning	Future Learning
IN.1.B.b			**IN.1.B.b** Measure length to the nearest millimeter, mass to the nearest gram, volume to the nearest milliliter, force (weight) to the nearest Newton, temperature to the nearest degree Celsius, time to the nearest second. DOK1	
IN.1.C.a			**IN.1.C.a** Use quantitative and qualitative data as support for reasonable explanations (conclusions). DOK3	
IN.1.C.b			**IN.1.C.b** Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable). DOK3	
IN.1.C.c			**IN.1.C.c** Identify the possible effects of errors in observations, measurements, and calculations, on the validity and reliability of data and resultant explanations (conclusions). DOK3	
IN.1.D.a			**IN.1.D.a** Communicate the procedures and results of investigations and explanations through: • Oral presentations • Drawings and maps • Data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities) • Graphs (bar, single and multiple line) • Equations and writings DOK3	

Lesson 8	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.A.b	CR2 DOK1 1.10 CR3 DOK2 1.10		**EC.1.A.b** Explain how cooperative (e.g., symbiotic) and competitive (e.g., predator/prey) relationships help maintain balance within an ecosystem. DOK2	
EC.1.B.a	MC1 DOK2 1.5		**EC.1.B.a** Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem. DOK2	
EC.1.B.b	**Pre/Post test:** MC19 DOK1 1.10 MC4 DOK2 1.10 CR5 DOK2 1.10 Match6 DOK1 1.8		**EC.1.B.b** Predict how populations within an ecosystem may change in number and/or structure in response to hypothesized changes in biotic and/or abiotic factors. DOK2	
EC.1.C.a	CR8 DOK1 1.10 MC9 DOK1 1.10 MC10 DOK3 1.3	EC.1.D.6.c DOK3	**EC.1.C.a** Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible adverse effects of human interactions with that ecosystem (e.g., destruction caused by direct harvesting, pollution, atmospheric changes). DOK3	
EC.1.C.b	CR12 DOK2 1.10		**EC.1.C.b** Predict and explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents). DOK2	
EC.1.D.a	**Pre/Post test:** MC20 DOK1 1.10		**EC.1.D.a** Predict the impact (beneficial or harmful) a natural or human caused environmental event (e.g., forest fire, flood, volcanic eruption, avalanche, acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on the diversity of different species in an ecosystem. DOK2	

Lesson 8	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.3.C	**Pre/Post test:** **MC1 DOK3 1.10**		**EC.3.C** Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	**LS.1.3** Genetic variation within populations: Students understand that genetic variation within a population is essential for natural selection. Mutations, as well as random assortment of existing genes, can produce genetic variation in a population.
EC.3.C.c			**EC.3.C.c** Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection. DOK2	
IN.1.A.a			**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	
IN.1.B.a			**IN.1.B.a** Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2	

Lesson 9	Assessment	Prior Learning	Targeted Learning	Future Learning
EC.1.C.a			**EC.1.C.a** Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible adverse effects of human interactions with that ecosystem (e.g., destruction caused by direct harvesting, pollution, atmospheric changes). DOK3	
IN.1.A.a			**IN.1.A.a** Formulate testable questions and hypotheses. DOK3	
IN.1.A.c			**IN.1.A.c** Design and conduct a valid experiment. DOK4	
IN.1.A.g			**IN.1.A.g** Evaluate the design of an experiment and make suggestions for reasonable improvements. DOK3	
IN.1.B.a			**IN.1.B.a** Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2	
IN.1.C.a			**IN.1.C.a** Use quantitative and qualitative data as support for reasonable explanations (conclusions). DOK 3	
IN.1.D.a			**IN.1.D.a** Communicate the procedures and results of investigations and explanations through: • Oral presentations • Drawings and maps • Data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities) • Graphs (bar, single and multiple line) • Equations and writings. DOK3	

CLEs Suggested for Ecology Teachers

DESE at this time has not designated CLEs specific to Ecology. Therefore, the Missouri Department of Conservation has identified the CLEs that are relevant to Ecology curriculum. These CLEs are recommended for a basic foundation for Ecology. There are CLEs in this chart that are not included in the *Nature Unbound* unit.

Strand 1: Properties and Principles of Matter and Energy

ME.1.I.a **1.** Changes in properties and states of matter provide evidence of the atomic theory of matter.	**I.** Mass is conserved during any physical or chemical change.	**a.** Compare the mass of the reactants to the mass of the products in a chemical reaction or physical change (e.g. biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, decomposition and synthesis reactions involved in a food web) as support for the Law of Conservation of Mass. DOK2
ME.2.A **2.** Energy has a source, can be stored, and can be transferred but is conserved within a system.	**A.** Forms of energy have a source, a means of transfer (work and heat), and a receiver	
ME.2.F.a **2.** Energy has a source, can be stored, and can be transferred but is conserved within a system.	**F.** Energy can be transferred within a system as the total amount of energy remains constant (i.e., Law of Conservation).	**a.** Classify the different ways to store energy (i.e. chemical, nuclear, thermal, mechanical, electromagnetic) and describe the transfer of energy as it changes from kinetic to potential, while the total amount of energy remains constant, within a system (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, food web). DOK2

Strand 3: Characteristic and Interactions of Living Organisms

LO.2.B.b **2.** Living organisms carry out life processes in order to survive.	**B.** Photosynthesis and cellular respiration are complementary processes necessary to the survival of most organisms on Earth.	**b.** Determine what factors affect the processes of photosynthesis and cellular respiration (i.e., light intensity, availability of reactants, temperature). DOK2
LO.2.D.c	**D.** Cells carry out chemical transformations that use energy for the synthesis or breakdown of organic compounds.	**c.** Recognize energy is absorbed or released in the breakdown and/or synthesis of organic compounds. DOK1

Strand 3: Characteristic and Interactions of Living Organisms	
LO.3.A.a **3.** There is a genetic basis for the transfer of biological characteristics from one generation to the next through reproductive processes.	**A.** Reproduction can occur asexually or sexually.	**a.** Distinguish between asexual (i.e., binary fission, budding, cloning) and sexual reproduction. DOK1
LO.3.D.a	**D.** There is heritable variation within every species of organism.	**a.** Describe the advantages and disadvantages of asexual and sexual reproduction with regard to variation within a population. DOK2
LO.3.D.c		**c.** Recognize that new heritable characteristics can only result from new combinations of existing genes or from mutations of genes in an organism's sex cells. DOK1

Strand 4: Changes in Ecosystems and Interactions of Organisms with their Environments	
EC.1.A.a **1.** Organisms are interdependent with one another and with their environment.	**A.** All populations living together within a community interact with one another and with their environment in order to survive and maintain a balanced ecosystem.	**a.** Explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (i.e., mutualism, commensalism, parasitism). DOK1
EC.1.A.b		**b.** Explain how cooperative (e.g., symbiotic) and competitive (e.g., predator/prey) relationships help maintain balance within an ecosystem. DOK2
EC.1.A.c		**c.** Explain why no two species can occupy the same niche in a community. DOK2 (The functional role of a species is not limited to its placement along a food pyramid; it also includes the interactions of a species with other organisms while obtaining food. For example, the methods used to tolerate the physical factors of its environment, such as climate, water, nutrients, soils, and parasites, are all part of its functional role. In other words, the ecological niche of an organism is its natural history: all the interactions and interrelationships of the species with other organisms and the environment.)
EC.1.B.a	**B.** Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite.	**a.** Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem. DOK2
EC.1.B.b		**b.** Predict how populations within an ecosystem may change in number and/or structure in response to hypothesized changes in biotic and/or abiotic factors. DOK2

Strand 4: Changes in Ecosystems and Interactions of Organisms with their Environments

Code	Concept	Detail
EC.1.C.a	**C.** All organisms, including humans, and their activities cause changes in their environment that affect the ecosystem.	**a.** Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible adverse effects of human interactions with that ecosystem (e.g., destruction caused by direct harvesting, pollution, atmospheric changes). DOK3
EC.1.C.b		**b.** Predict and explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents). DOK2
EC.1.D.a	**D.** The diversity of species within an ecosystem is affected by changes in the environment, which can be caused by other organisms or outside processes.	**a.** Predict the impact (beneficial or harmful) a natural or human caused environmental event (e.g., forest fire, flood, volcanic eruption, avalanche, acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on the diversity of different species in an ecosystem. DOK2
	1. Organisms are interdependent with one another and with their environment.	
EC.1.D.b		**b.** Describe possible causes of extinction of a population. DOK1
EC.2.A.a	**A.** As energy flows through the ecosystem, all organisms capture a portion of that energy and transform it to a form they can use	**a.** Illustrate and describe the flow of energy within a food web. DOK2
	2. Matter and energy flow through the ecosystem.	
EC.2.A.b		**b.** Explain why there are generally more producers than consumers in an energy pyramid. DOK2
EC.2.A.c		**c.** Explain why there are generally more producers than consumers in an energy pyramid. DOK2
EC.2.B.a	**B.** Matter is recycled through an ecosystem.	**a.** Explain the processes involved in the recycling of nitrogen, oxygen, and carbon through an ecosystem. DOK2
EC.2.B.b		**b.** Explain the importance of the recycling of nitrogen, oxygen, and carbon within an ecosystem. DOK1
EC.3.C.a	**C.** Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem.	**a.** Identify examples of adaptations that may have resulted from variations favored by natural selection (e.g., long-necked giraffes, long-eared jack rabbits) and describe how that variation may have provided populations an advantage for survival. DOK2
	3. Genetic variation sorted by the natural selection process explains evidence of biological evolution.	
EC.3.C.b		**b.** Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance). DOK2
EC.3.C.c		**c.** Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection. DOK2
EC.3.C.d		**d.** Given a scenario describing an environmental change, hypothesize why a given species was unable to survive. DOK2

Strand 7: Scientific Inquiry

IN.1.A.a **1.** Science understanding is developed through the use of science process skills, scientific knowledge, scientific investigation, reasoning, and critical thinking.	**A.** Scientific inquiry includes the ability of students to formulate a testable question and explanation, and to select appropriate investigative methods in order to obtain evidence relevant to the explanation.	**a.** Formulate testable questions and hypotheses. DOK3
IN.1.A.b		**b.** Analyzing an experiment, identify the components (i.e., independent variable, dependent variables, control of constants, multiple trials) and explain their importance to the design of a valid experiment. DOK3
IN.1.A.c		**c.** Design and conduct a valid experiment. DOK4
IN.1.A.d		**d.** Recognize it is not always possible, for practical or ethical reasons, to control some conditions (e.g., when sampling or testing humans, when observing animal behaviors in nature). DOK2
IN.1.A.g		**g.** Evaluate the design of an experiment and make suggestions for reasonable improvements. DOK3
IN.1.B.a	**B.** Scientific inquiry relies upon gathering evidence from qualitative and quantitative observations.	**a.** Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, analog and digital meters, computers, spring scales, balances, metric rulers, graduated cylinders). DOK2
IN.1.B.b		**b.** Measure length to the nearest millimeter, mass to the nearest gram, volume to the nearest milliliter, force (weight) to the nearest Newton, temperature to the nearest degree Celsius, time to the nearest second. DOK1
IN.1.B.c		**c.** Determine the appropriate tools and techniques to collect, analyze, and interpret data. DOK2
IN.1.B.d		**d.** Judge whether measurements and computation of quantities are reasonable. DOK2
IN.1.B.e		**e.** Calculate the range, average/mean, percent, and ratios for sets of data. DOK1
IN.1.B.f		**f.** Recognize observation is biased by the experiences and knowledge of the observer (e.g., strong beliefs about what should happen in particular circumstances can prevent the detection of other results). DOK2
IN.1.C.a **1.** Science understanding is developed through the use of science process skills, scientific knowledge, scientific investigation, reasoning, and critical thinking.	**C.** Scientific inquiry includes evaluation of explanations (laws/principles, theories/models) in light of evidence (data) and scientific principles (understandings).	**a.** Use quantitative and qualitative data as support for reasonable explanations (conclusions). DOK3

Strand 7: Scientific Inquiry

IN.1.C.b	**b.** Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable). DOK3
IN.1.C.c	**c.** Identify the possible effects or errors in observations, measurements, and calculations, on the validity and reliability of data and resultant explanations (conclusions). DOK3
IN.1.D.a **D.** The nature of science relies upon communication of results and justification of explanations.	**a.** Communicate the procedures and results of investigations and explanations through: • oral presentations • drawings and maps • data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities) • graphs (bar, single, and multiple line) • equations and writings DOK: 3

Strand 8: Impact of Science, Technology and Human Activity

ST.1.A.a **1.** Historical and cultural perspectives of scientific explanations help to improve understanding of the nature of science and how science knowledge and technology evolve over time.	**A.** People of different gender and ethnicity have contributed to scientific discoveries and the invention of technological innovations.	**a.** Recognize contributions to science are not limited to the work of one particular group, but are made by a diverse group of scientists representing various ethnic and gender groups. DOK1
ST.2.B **2.** Historical and cultural perspectives of scientific explanations help to improve understanding of the nature of science and how science knowledge and technology evolve over time	B. Scientific theories are developed based on the body of knowledge that exists at any particular time and must be rigorously questioned and tested for validity	
ST.3.A **3.** Science and technology affect, and are affected by, society.	**A.** People, alone or in groups, are always making discoveries about nature and inventing new ways to solve problems and get work done.	

Misconception Assessment for *Nature Unbound*

Gathering Prior Knowledge

True	False	Statement about Ecology
		1. Ecologists primarily study and save endangered animals.
		2. Nature is divided into two parts—biotic and abiotic.
		3. The Biosphere is made up of ecosystems, communities and populations.
		4. Ecologists observe ecosystems to collect data and ask questions.
		5. Adaptations of organisms can be observable within a generation.
		6. Reproduction is essential to the survival of individual organisms – not the species as a whole.
		7. Organisms only reproduce sexually.
		8. Missouri doesn't have endangered species.
		9. The growth rate in a population determines the hunting limits in Missouri.
		10. Deer are a keystone species in Missouri.
		11. Half of the energy in a food web passes to the next trophic level.
		12. Organisms intentionally affect changes in body structure.
		13. Dead organisms simply rot away, and their material disappears.
		14. There are more consumers than producers in a food chain.

Misconception Assessment for *Nature Unbound*
Answer Sheet

Gathering Prior Knowledge

True	False	Statement about Ecology
	✓	**1.** Ecologists primarily study and save endangered animals.
✓		**2.** Nature is divided into two parts—biotic and abiotic.
✓		**3.** The Biosphere is made up of ecosystems, communities and populations.
✓		**4.** Ecologists observe ecosystems to collect data and ask questions.
	✓	**5.** Adaptations of organisms can be observable within a generation.
	✓	**6.** Reproduction is essential to the survival of individual organisms – not the species as a whole.
	✓	**7.** Organisms only reproduce sexually.
	✓	**8.** Missouri doesn't have endangered species.
	✓	**9.** The growth rate in a population determines the hunting limits in Missouri.
	✓	**10.** Deer are a keystone species in Missouri.
	✓	**11.** Half of the energy in a food web passes to the next trophic level.
	✓	**12.** Organisms intentionally affect changes in body structure.
	✓	**13.** Dead organisms simply rot away, and their material disappears.
	✓	**14.** There are more consumers than producers in a food chain.

Pre/Post Assessment for *Nature Unbound*

1. Which definition *best* describes ecology?
    a. Study of biology including cellular processes
    b. Study of ecologists including the work that they do
    c. Study of how nature works including both abiotic and biotic factors
    d. Study of populations including disease within populations

2. Which statement *best* describes conservation's role in society?
    a. Conservation practices manage resources for the next generations to have and also use
    b. Conservation educates the public about ways that they can help Missouri animals
    c. Conservation educates landowners about the best way to manage ponds
    d. Conservation practices allow for ecologists to study nature

3. Ecologists work by:
    a. First developing a question and then setting up an experiment
    b. First developing a question and then looking up the answers in credible sources
    c. First developing a question and then creating a model
    d. Both a and b
    e. Both a and c

Use the following scenario to answer question 4, 5 and 6.

Mead's milkweed is an endangered species in Missouri. It is self-incompatible which means it produces seeds only when pollen from one plant reaches the flower of a different plant. Mead's milkweed can also spread by sprouting stems from a long underground rhizome.

4. Which reproduction strategy does Mead's milkweed utilize?
    a. Asexual reproduction
    b. Sexual reproduction
    c. Both a and b
    d. Unilateral reproduction

5. The greatest genetic diversity can be found in which colony of Mead's milkweed?
    a. A colony that is treated with pesticides
    b. A colony that reproduces by seed and vegetative reproduction
    c. A colony that is located in Missouri
    d. A colony that reproduces only by vegetative reproduction

6. Which species would have the best chance of survival?
    a. A species that has a population of genetically similar individuals
    b. A species that has a very small population
    c. A species that has a population of genetically different individuals
    d. A species that has a very large population

7. What keeps species' populations from exploding? Choose the best answer.
   a. Abiotic factors
   b. Biotic factors
   c. Limiting factors
   d. Reproductive factors

8. Key measurements of a population that ecologists make are:
   a. Size, number of predators and carrying capacity
   b. Size, density and carrying capacity
   c. Size, density and dispersion
   d. Size, carrying capacity and dispersion

9. What would happen, over time, if two species occupied the exact same niche?
   a. One would outcompete the other
   b. One would kill the other
   c. One would become dependent on the other
   d. One would mate with the other

10. Imagine that the large mammalian predators have been eliminated in an area. What would be the impact to the ecosystem over time? Choose the best answer.
    a. Prey species would increase exponentially
    b. The balance of the ecosystem would be restored
    c. The balance of the ecosystem would be upset
    d. Other species would not be impacted

11. Which combination of characteristics bests describes a species most likely to go extinct?
    a. Small population with a small home range
    b. Large population with a large home range
    c. Small population with a large home range
    d. Large population with a small home range

12. Which of the following is the major factor causing extinction of a species?
    a. Hunting
    b. Habitat destruction or fragmentation
    c. Being hit by a car
    d. Competition of a non-native species

13. Why are there usually fewer than five levels in an energy pyramid?
    a. Almost 90% of the energy in the first level is transferred to primary consumers
    b. Six levels would be too many
    c. Energy is lost as it is transferred to each trophic level, making less energy available at each higher trophic level
    d. There are too many top level predators

14. Suppose muskrats living in a marsh are overharvested. How would the flow of energy be altered? Choose the best answer.
    a. Less dominant wetland plants would not survive.
    b. The marsh would have greater diversity of herbivores.
    c. Cattails would dominate the marsh.
    d. Both a and c

For questions 15-18, match the description with the appropriate abiotic cycle. Answers may be used once, more than once, or not at all.
   a.   Water Cycle
   b.   Nitrogen Cycle
   c.   Carbon Cycle
   d.   Phosphorus Cycle

15. Needed for plants to make amino acids and DNA.

16. Transpiration is a process in plants that is part of this cycle.

17. Precipitation ➝ Runoff ➝ Percolation are all processes in this cycle.

18. A large amount of this element is stored as fossil fuels.

19. Which community is more stable?
   a.   One with a large biodiversity
   b.   One with a small biodiversity
   c.   One with a large variety of plant species
   d.   One with a mall

20. A tornado cuts a path through the Mark Twain National Forest. The trees in the forest were leveled, creating large swaths of open areas. Which answer best describes the succession stages that would follow this occurrence?
   a.   Small trees followed by perennial plants and woody vegetation, followed by larger trees followed by a forest
   b.   Annual plants followed by perennial plants and woody vegetation, followed by small trees, followed by forest
   c.   Small trees followed by larger trees, followed by a forest
   d.   People move in and subdivide the area into housing tracts

Pre/Post Test Questions and Answers for *Nature Unbound*

1. Which definition *best* describes ecology?
   a. Study of biology including cellular processes
   b. Study of ecologists including the work that they do
   c. Study of how nature works including both abiotic and biotic factors
   d. Study of populations including disease within populations
   Answer: c

2. Which statement *best* describes conservation's role in society?
   a. Conservation practices manage resources for the next generations to have and also use
   b. Conservation educates the public about ways that they can help Missouri animals
   c. Conservation educates landowners about the best way to manage ponds
   d. Conservation practices allow for ecologists to study nature
   Answer: a

3. Ecologists work by:
   a. First developing a question and then setting up an experiment
   b. First developing a question and then looking up the answers in credible sources
   c. First developing a question and then creating a model
   d. Both a and b
   e. Both a and c
   Answer: e

Use the following scenario to answer question 4,5 and 6.

Mead's milkweed is an endangered species in Missouri. It is self-incompatible which means it produces seeds only when pollen from one plant reaches the flower of a different plant. Mead's milkweed can also spread by sprouting stems from a long underground rhizome.

4. Which reproduction strategy does Mead's milkweed utilize?
   a. Asexual reproduction
   b. Sexual reproduction
   c. Both a and b
   d. Unilateral reproduction
   Answer: c

5. The greatest genetic diversity can be found in which colony of Mead's milkweed?
   a. A colony that is treated with pesticides
   b. A colony that reproduces by seed and vegetative reproduction
   c. A colony that is located in Missouri
   d. A colony that reproduces only by vegetative reproduction
   Answer: b

6. Which species would have the best chance of survival?
    a. A species that has a population of genetically similar individuals
    b. A species that has a very small population
    c. A species that has a population of genetically different individuals
    d. A species that has a very large population
    Answer: c

7. What keeps species' populations from exploding? Choose the best answer.
    a   Abiotic factors
    b.   Biotic factors
    c.   Limiting factors
    d.   Reproductive factors
    Answer: c

8. Key measurements of a population that ecologists make are:
    a.   Size, number of predators and carrying capacity
    b.   Size, density and carrying capacity
    c.   Size, density and dispersion
    d.   Size, carrying capacity and dispersion
    Answer: c

9. What would happen, over time, if two species occupied the exact same niche?
    a.   One would outcompete the other
    b.   One would kill the other
    c.   One would become dependent on the other
    d.   One would mate with the other
    Answer: a

10. Imagine that the large mammalian predators have been eliminated in an area. What would be the impact to the ecosystem over time: Choose the best answer.
    a.   Prey species would increase exponentially
    b.   The balance of the ecosystem would be restored
    c.   The balance of the ecosystem would be upset
    d.   Other species would not be impacted
    Answer: c

11. Which combination of characteristics bests describes a species most likely to go extinct?
    a.   Small population with a small home range
    b.   Large population with a large home range
    c.   Small population with a large home range
    d.   Large population with a small home range
    Answer: a

12. Which of the following is the major factor causing extinction of a species?
    a.   Hunting
    b.   Habitat destruction or fragmentation
    c.   Being hit by a car
    d.   Competition of a non-native species
    Answer: b

13. Why are there usually fewer than five levels in an energy pyramid?
    a. Almost 90% of the energy in the first level is transferred to primary consumers.
    b. Six levels would be too many
    c. Energy is lost as it is transferred to each trophic level, making less energy available at each higher trophic level
    d. There are too many top level predators
    Answer: c

14. Suppose muskrats living in a marsh are overharvested. How would the flow of energy be altered? Choose the best answer.
    a. Less dominant wetland plants would not survive.
    b. The marsh would have greater diversity of herbivores.
    c. Cattails would dominate the marsh.
    d. Both a and c
    Answer: d

For question 15 - 18 match the description with the appropriate abiotic cycle. Answers may be used once, more than once, or not at all.
    a. The Water Cycle
    b. The Nitrogen Cycle
    c. The Carbon Cycle
    d. The Phosphorus Cycle

15. Needed for plants to make amino acids and DNA.
    Answer: b

16. Transpiration is a process in plants that is part of this cycle.
    Answer: a

17. Precipitation → Runoff → Percolation are all processes in this cycle.
    Answer: a

18. A large amount of this element is stored as fossil fuels.
    Answer: c

19. Which community is more stable?
    a. One with a large biodiversity
    b. One with a small biodiversity
    c. One with a large variety of plant species
    d. One with a mall
    Answer: a

20. A tornado cuts a path through the Mark Twain National Forest. The trees in the forest were leveled, creating large swaths of open areas. Which answer best describes the succession stages that would follow this occurrence?
    a. Small trees followed by perennial plants and woody vegetation followed by larger trees followed by a forest.
    b. Annual plants followed by perennial plants and woody vegetation followed by small trees followed by forest.
    c. Small trees followed by larger trees, followed by a forest.
    d. People move in and subdivide the area into housing tracts.
    Answer: b

Materials List

Air thermometers
Biltmore sticks
Calculators
Collection jars or other containers for live invertebrates
Colored markers
Flagging tape
Forceps
Golf tees—100 white, 100 green, 75 blue, 75 red, 25 tan
Hula hoops/yardsticks/rope
Insect field guide
Insect nets
Magnifiers
Metric rulers/metric measuring tapes
Nail polish
"Odyssey" essay from *Sand County Almanac*, by Aldo Leopold
Orange cones or tent stakes
Poster board
Rolls of adding machine paper or toilet paper
Rope
Safety goggles and gloves
Scissors
Soil or water test kits or probes for nitrogen and or phosphorus
    (These may be available by loan from a county soil and water conservation agency.)
Soil thermometers
Tokens—20 each of three colors
Tree field guide
Weather data collection equipment
    (anemometers, sling psychrometers, light meters, Kestrel, etc.)
Yarn

Lesson 1: What is Ecology?

Estimated time
(4) 50-minute class periods

Science CLEs

EC.1.A. All populations living together within a community interact with one another and with their environment in order to survive and maintain a balanced ecosystem

EC.1.B.a. Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem

IN.1.A.a. Formulate testable questions and hypotheses

IN.1.B.a. Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., ~~microscopes~~, thermometers, analog and digital meters, computers, ~~spring scales~~, ~~balances~~, metric rulers, ~~graduated cylinders~~)

IN.1.C.a. Use quantitative and qualitative data as support for reasonable explanations (conclusions)

ST.3.A. People, alone or in groups, are always making discoveries about nature and inventing new ways to solve problems and get work done

Vocabulary

Biotic	Population size
Abiotic	Community
Atoms	Ecosystem
Molecules	Biosphere
Organelles	Hypothesis
Cells	Independent variable
Tissues	Dependent variable
Organs	Experimental group
Organism	Control group
Population	Natural resource manager

Objectives

1. Define ecology.

2. Describe the scope of ecology.

3. Illustrate and explain how organism, population, community, ecosystem and biosphere are connected.

4. Explain how ecologists conduct research and give examples of questions ecologists might ask at each level of focus from organism to biosphere.

5. Explain why ecology is important.

Resource Management Objectives

1. Explain the relationship between resource management and ecology.

2. Define conservation and its importance to society.

Essential Questions

1. What is ecology and why is it important?

2. How do ecologists organize nature?

Teacher Notes

Students should read *Nature Unbound* Chapter 1 before beginning Lesson 1 activities.

The area around the school (hereafter referred to as the schoolyard ecosystem) will suffice for activities developed to be taught outdoors. Page 2 of this teacher guide provides brief tips and information on preparing for outdoor activities. Science notebooking is an important component of this unit. Page 4 of this guide provides information on the purpose and process of using science notebooks. It is suggested that you review with your students how to keep a science notebook before starting the *Nature Unbound* unit.

As part of their science notebooks, students will be required to record basic abiotic factors such as weather conditions, temperature, light intensity, humidity, etc. depending on the equipment available. This should be done with every activity. Recording temperature with each activity will allow students to collect data over time and correlate organisms observed to weather conditions. As students collect this data, they can create charts or graphs to organize it. Students should also be encouraged to correlate abiotic data with biotic data. Have students summarize their correlations (ex. How does weather affect the number of animal species observed? How does weather affect animal behavior? How does weather affect plant growth?)

Weather data can be obtained on the Internet at a weather data site and/or taken in the field.

Outline of Answers to Objectives

See following page.

Essential Activities

Essential Activity 1.1—Schoolyard Ecosystem–Biotic and Abiotic Factors
Essential Activity 1.2—Ecology–The Big Picture: Examine the Parts to Make a Whole
Essential Activity 1.3—Establishing Study Sites and Collecting Data

End of Chapter Assessment

Lesson 1 Questions and Answer Key

Summary

- Ecology is the study of how nature works.
- Ecologists study things as small as individual organisms or as large as the biosphere.
- Ecologists make observations, ask questions and collect data.
- Understanding ecology is important for many reasons.

Outline of Answers to Objectives

1. **Define ecology**. (*Nature Unbound* p. 4)
   a. Ecology is the study of how nature works.
      i. Two basic components:
         1. The biotic (living) part of nature is composed of plants, animals, fungi, protists and bacteria—anything that is alive.
         2. The abiotic (nonliving) part is composed of the physical and chemical components of the environment, including water, sunlight, temperature, oxygen and soil chemistry.
      ii. Any living thing is affected by and responds to both biotic and abiotic parts of its environment. Likewise, abiotic parts of the environment are affected by living things. Ecologists seek to understand these relationships.

2. **Describe the scope of ecology**. (p. 4)
   a. Ecologists study things as small as individual organisms or as large as the biosphere.

3. **Illustrate and explain how organism, population, community, ecosystem and biosphere are connected**. (pp. 5-8)
   a. Ecologists studying an organism (a single living thing) try to learn how living things are affected by and respond to their environment.
   b. Ecologists studying a population (a group of the same kind of organisms living together in the same place at the same time) try to learn what factors contribute to an increase or decrease in the population's size.
   c. Ecologists studying communities (groups of different populations living in the same place at the same time) try to figure out how various interactions affect the populations involved.
   d. Ecologists studying ecosystems (a community along with the abiotic factors of the environment) try to understand how energy is transferred from the sun through different organisms that feed upon each other; how atoms essential for life cycle through both abiotic and biotic parts of the ecosystem; and how physical processes, such as fire or flooding, affect the communities in the ecosystem.
   e. Ecologists studying the biosphere (the layer of our planet that supports and contains every living thing) try to understand how global processes affect different ecosystems. Ecologists study how things in one ecosystem affect other ecosystems.

4. **Explain how ecologists conduct research and give examples of questions ecologists might ask at each level of focus from organism to biosphere**. (p. 9)
   a. Ecologists make observations, ask questions and collect data.
      i. Observations lead to questions.
      ii. The ecologist then writes a hypothesis to answer the question. A hypothesis contains:
         1. Independent variable (changed or manipulated in some way)
         2. Dependent variable (reacts to changes made to the independent variable)
      iii. To test the hypothesis, the ecologist collects data using observations, experiments, models or a combination of the three.
      iv. Then the ecologist analyzes and interprets the data, often using mathematics and statistics to see if it supports or disproves the hypothesis. This often leads to more questions.
      v. Examples of questions ecologists might ask:
         1. Organism: How does water temperature affect bullfrog behavior?
         2. Population: How many river otters can the Grand River watershed support?
         3. Community: Do red-winged blackbirds and marsh wrens compete for nesting sites?
         4. Ecosystem: How fast does nitrogen move through a wetland ecosystem?
         5. Biosphere: How much carbon do Missouri wetlands remove from Earth's atmosphere?

5. **Explain why ecology is important**. (p. 13)
   a. Ecological systems provide the life support functions all life needs.
   b. Ecological systems provide us with an infinite number of products.
   c. If the Earth's life support systems break down, we need to know how to fix them. Ecology gives us a way to learn how these systems work, recognize when they are failing and provide ideas for fixing problems. Our life depends on it. That is why understanding ecology is important.

Resource Management Objectives

1. **Explain the relationship between resource management and ecology**. (p. 10)
   a. Although ecology and resource management are related, they are not the same.
   b. Ecology is a pure science; resource management is an applied science.
   c. In the same way that medical doctors apply knowledge learned from anatomy and physiology to maintain and restore the health of their patients, resource managers apply principles learned from ecology to protect, maintain and restore healthy ecosystems.

2. **Define conservation and its importance to society**. (p. 12)
   a. Conservation is a way of using resources that keeps them healthy and intact for use by future generations.
   b. Because we all depend upon the Earth's ecosystems for food, water, clothing and shelter, it's important to realize that maintaining the harmony between people and land is a responsibility for all of us. Learning about ecology is one way you can gain the knowledge to make wise decisions about how you use natural resources.

Essential Activity 1.1
Schoolyard Ecosystem—Biotic and Abiotic Factors

Estimated time
(1) 50-minute class period

Objectives
Students will be able to:
1. Identify biotic and abiotic factors.

2. Explain how ecologists conduct research.

3. Create a base line study for future investigations.

Teacher Preparation
This activity serves as an introduction to going outdoors and using science notebooks, both important elements of this unit. Develop a management plan for conducting activities outdoors with students.

For this activity, a portion of the schoolyard ecosystem (the area within the schoolyard, around or near the school and/or an outdoor classroom) should be divided into study areas using available materials. (Hula hoops work well to set off small areas; sets of four meter sticks can be arranged in a square; rope or string heavy enough not to be disturbed by wind can also be arranged in a circle shape to set off an area.) Students should work in teams to survey assigned study areas. Students should record all abiotic and biotic factors they observe and organize the information themselves or use the charts provided and store them in their science notebooks at the end of the activity.

If students are unfamiliar with data collection techniques, practice inside by setting up "study sites" within the classroom. Place "organisms" such as everyday items from your classroom or outside within these sites. Practice using sampling tools like thermometers to collect and chart data.

Materials
Student science notebooks
Pencils
Air thermometers
Copies of *1.1 Biotic/Abiotic Chart* (if needed)
Hula hoops, or meter sticks and rope/heavy string, or flagging tape, etc.

Procedure
1. Review the plan for outside activities with students and separate them into groups of three or four *before* leaving the classroom.

2. Have students prepare their science notebook page by creating the standard headings:
   a. Title
   b. Date
   c. Time
   d. Location
   e. Air temperature (recorded outside)
   f. Weather conditions (recorded outside) such as cloud cover, wind speed and direction, humidity, etc.

3. Have students create a map of the schoolyard ecosystem, or have students use a map program like Google Earth to familiarize themselves with the areas available for study. If space allows, have students set out several study areas and assign at least one group per area.

4. Review definitions of biotic and abiotic factors or use completed student observation charts to assess prior knowledge of these terms.

5. Instruct students to record all abiotic and biotic factors and the number of each within their assigned area. Students should estimate numbers that are too abundant to count individually within a study area (ex. clover flowers > 100; blades of grass > 1000).

6. Provide students sufficient time to survey their area and to record their observations.

7. Instruct students to record two things they were curious about during their observation and write a question for each.

8. While outside:
   a. Discuss how students might compile their data to lay the groundwork for future investigations.
   b. Review for accuracy and discuss student entries from the *1.1 Biotic/Abiotic Charts* (check that students included plants and animals as biotic factors):
      1. What factors, if any, were difficult to label as biotic or abiotic?
      2. How did the weather conditions affect what they saw?
      3. What biotic and abiotic factors did they expect to find?
      4. What factors were they surprised to find?
      5. How might a natural area or conservation area manager use the information collected?
   c. Have students write a short summary of the data collected.

9. Have students retrieve study area materials.

10. Back in the classroom:
    a. List student questions on the board.
    b. Have students discuss and define what it means to have a "testable" question.
    c. Discuss which questions could be made into testable questions.
    d. Have students write a hypothesis for one of their questions.

Wrap up

1. Have students discuss the following:
   a. How did weather conditions affect what they saw?
   b. Were they surprised to find something in particular?
   c. Were they surprised not to find something they had expected would be there?

2. Why would someone managing a natural area or conservation area need to know the information collected?

Assessment

Check student charts for accuracy and completion. Set a minimum number for each factor, biotic and abiotic.

1.1 Biotic/Abiotic Chart

Directions: Record observations of your study site. Check if the factor is biotic or abiotic and record the number observed. Record any notes or questions in the space provided. Summarize your observations at the bottom of this chart.

Observed Factor	Biotic ✓	Abiotic ✓	#	Notes/Questions

Summary:

Essential Activity 1.2
Ecology—The Big Picture: Examine the Parts to Make a Whole

Estimated time
(1) 50-minute class period

Objectives
Students will be able to:
1. Define ecology.

2. Explain how organism, population, community, ecosystem and biosphere are connected.

3. Explain how ecologists conduct research and give examples of questions ecologist might ask at each level of focus from organism to biosphere.

Teacher Preparation
This activity should help determine what students already know or think they know about ecology and key foundation terminology related to ecology.

Select an area in your schoolyard ecosystem that exhibits plant and animal diversity. The area does not need to be large. Even a small area of lawn can reflect the basic components of an ecosystem: one ant is an organism; a group of ants is a population; the population of ants interacting with plants and other animals within the area forms a community; all the communities interacting with the abiotic factors form an ecosystem.

Materials
Student science notebooks
Pencils/pens
Air thermometers

Procedure
1. Review the plan for outside activities and have students complete science notebook headings. For this activity, students should work independently.

2. Have students organize the following prompts and levels of focus (related to questions an ecologist might ask during an area study) in their science notebooks as a table or other graphic organizer. Students may reference pages 5-8 of their student book for examples of ecologist's questions:
   a. Organism—species observed—description—question an ecologist would ask
   b. Population—species observed—description—question an ecologist would ask
   c. Community—species observed—description—question an ecologist would ask
   d. Ecosystem—species observed—description—question an ecologist would ask

3. It is important that students understand the importance of describing and/or sketching an organism with as much detail as possible in order to use the description and/or sketch to identify that organism at a later time. For example, are the leaves of a plant alternate or opposite? What do the edges of the leaves look like? Are they smooth or serrate? If the plant has a flower, what is the color of the flower? How many petals does it have?

4. Once outdoors, explain the boundaries for data collection and the time limit.

5. Instruct students to move slowly and carefully through the area to find examples of each ecosystem component recorded in their science notebooks. Ecosystem components should be named/identified and described and sketched in detail.

6. Have students summarize their findings.

7. When observation time is over, have students work in small groups to share their findings and discuss why or why not shared examples are valid.

8. Allow students to change and add to their findings.

9. Have students write a question an ecologist might ask by each ecosystem component. For example, a notebook page showing information for "organism" as the level of focus might read:
   a. Organism: purple coneflower
   b. Description: 140 cm in height, large purple showy flower head that is daisy-like (composite), stem and leaves are dark green and feel rough
   c. Sketch and label the parts of purple coneflower.
   d. Question an ecologist would ask: How does light intensity affect the growth of this flower?

10. Discuss the term biosphere and how it relates to Missouri.
   a. Discuss the meaning of the prefix *bio* and the root *sphere*.
   b. The biosphere encompasses more than Missouri.
   c. The biosphere is all ecosystems on the Earth where life is found, from the deepest ocean trenches to the tallest mountain.
   d. The biosphere includes ecosystems in exotic locations that students may have studied such as those in Africa and South America.

Wrap up

1. Have students share questions recorded for each level of focus. Write these on the board. Are any testable? For those that are not, how can they be made into testable questions?

2. Have students share descriptions and sketches created for each level of focus. Would they be able to identify the organisms from the information recorded? Was the description complete enough? Were the labels accurate?

Assessment

Check notebooks and graphic organizer (if created) for completion and accuracy.

Extensions

1. If they have not already done so, have students create a graphic organizer to represent organism—population—community—ecosystem—biosphere. Students should use the examples observed and recorded in the schoolyard ecosystem.

2. Have students take digital photos of their observations. Include the photos with the data recorded.

Essential Activity 1.3
Establishing Study Sites and Collecting Data

Estimated time
(2) 50-minute class periods

Objectives
Students will be able to:
1. Define ecology.

2. Learn how ecologists make observations, ask questions and collect data.

Teacher Preparation
Ecologists divide nature into two basic parts: biotic and abiotic. A key theme of ecology is that all living things are affected by and respond to both biotic and abiotic factors within their environment. Likewise, biotic and abiotic factors are affected by living things. Ecologists seek to understand these relationships.

Prior to the activity, locate three areas of similar size with different habitats within or nearby the schoolyard. Some examples of potential areas include a sidewalk, playground, mowed lawn, sports field, woods or tall grass/weedy area. The three areas should be different from each other, but one of the chosen areas must reflect plant and animal diversity.

- Place four meter sticks together to create a square meter. Place a square meter within each of the three areas (or a hula hoop or a circle of rope equivalent in size to a hula hoop). Each square meter represents a different study site. You may also run a straight line transect and collect information along the transect by randomly placing the square meter and collecting the information inside the square.
- Number each study site.
- Students should work in groups of three to record data gathered at all three areas.
- Either have groups determine how they will record and organize data or provide enough data sheets for students to record all data gathered by their group. Data sheets should be kept in science notebooks.
- Determine if students should identify plants and animals in the field or collect them to identify in the classroom. If collecting animals, please see page 9 of the Forward to the teacher guide.

If students capture and release monarch butterflies in the fall, they may want to participate in Project Monarch Watch. www.monarchwatch.org

Materials
Student science notebooks
Pencils
4 meter sticks to form a square meter or 3 hula hoops or 3 circles of rope roughly equivalent in size to a hula hoop
3 Air thermometers
3 Ground thermometers
*3 Sling psychrometers—if available or go online to find the humidity reading
*3 Soil moisture meters—or use a dry tissue to determine soil moisture
*3 Beaufort wind scale meters (See end of lesson.)
Optional: Copies of *1.3 Data Sheets* (one of each of these three data sheets per student): *1.3 Abiotic Data;*
1.3 Biotic Data—Plants; 1.3 Biotic Data—Animals; light meters; digital lab probes

Procedure

1. Have students complete science notebook headings.

2. Review proper use of data collection equipment, if necessary.

3. Once outside at the study site, instruct students:
   a. To work in groups of three: each group should collect the following for each of the 3 study sites:
      i. Abiotic data
      ii. Biotic data pertaining to plants
      iii. Biotic data pertaining to animals and/or evidence of animals at each site
   - Unless copies of data sheets provided in this teacher guide are being used, groups should decide how they want to capture and organize data. Although students are working in groups to record data, each student is responsible for having a complete set of data sheets.
   - Duties should switch with each area studied, and students should assist each other with collection of all data. *Note*: If time does not allow for all the groups to collect data at all three sites, assign groups to one or two sites. Have groups share data with other groups so that each group has data for all three sites.

4. At the conclusion of data recording, students should:
   a. Create a table/graph for the abiotic data comparing the three sites.
   b. Create a table/graph for the biotic data related to plants comparing the three sites.
   c. Create a table/graph for the biotic data related to animals comparing the three sites.

5. Analyze the data and write a summary.

6. The following questions can be used as prompts:
   a. At which site was the temperature highest? Why would the temperature be highest there?
   b. At which site was the greatest diversity of plants observed? Why do you think this site had so much plant diversity?
   c. At which site was the greatest diversity of animals observed? Why would this site have so much animal diversity?
   d. Which biotic factor showed the greatest difference between all three sites? Why would this site reflect such a difference from the other two sites?
   e. List one question you wondered about during data collection.

7. Have groups share and compare data.
   a. Which site has the most diversity?
   b. What factor(s) make that site most diverse?

Wrap up

1. Compile a list of questions that can be created from the data collected.

2. Determine which questions are testable.

3. For those questions that are not testable, change them into testable questions.

Assessment

Data collection sheets can be used for assessment. See *Appendix 1: Scoring Guide for Data Sheets*, page 213. A minimum number of plants and animals can be set.

Extensions

1. Collect data from the same sites seasonally. What are the changes?

2. Keep information from year to year. What are the changes?

3. Measure the height of plants within the study sites. Graph the results. Compare the three areas.

4. Have students:
    a. Create maps by observing the area.
    b. Create maps using Google Earth or other computer programs.
    c. Use GPS units to mark where animals were collected.

1.3 Abiotic Data Sheet

Directions: Complete the data sheet for your study site. Fill in site # or name and complete the site description. Use the appropriate thermometer for air and soil temperatures. Use a sling psychrometer for a humidity reading or visit a weather data website. If available, use a moisture meter for soil moisture or determine whether it is dry, damp or wet by using your finger or a tissue. Press your finger or the tissue against the bare soil. If the soil is wet, record wet; if damp, record damp; if dry, record dry. For light/shade reading, use a light meter if available, or place a piece of notebook paper on the plot and estimate how much of the paper is covered by shadow. For wind speed see the *Beaufort Wind Speed Chart*.

Team members: _____

Date: _____ Time: _____

Weather Conditions: _____

Site #	Site Description	Air Temp °C	Soil Temp °C	% Humidity	Soil Moisture	% Light/ Shade

1.3 Biotic Data—Plants

Directions: Record the site number and percent of ground covered by herbaceous vegetation. Complete the data chart below. Record *all* visible plants within the study site (square meter). Use field guides to identify the plants. Draw, describe and label any plants you are unable to identify with a species number (ex. Species 1, Species 2). More than one of these sheets may be needed.

Site Number _____

_____ Percent of ground covered by herbaceous vegetation within the square meter (ex. < 25%, 50%, 75%)

Plant Description	Common Name	Scientific Name	Estimated #

1.3 Biotic Data—Animals

Directions: Complete the chart below. Record and describe all evidence of animals visible within the square meter. Remember that insects are animals.) Use field guides to determine animal species. Draw, describe and label any animals you are unable to identify with a species number (ex. Species 1, Species 2). More than one of these sheets may be needed.

Site Number _____

Animal Description/ Animal Sign	Common Name	Scientific Name	Estimated #

Beaufort Wind Scale

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects On Land
0	Less than 1	Calm	Calm, smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-6	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	7-10	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	11-16	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	17-21	Fresh Breeze	Small trees in leaf begin to sway
6	22-27	Strong Breeze	Larger tree branches moving, whistling in wires
7	28-33	Near Gale	Whole trees moving, resistance felt walking against wind
8	34-40	Gale	Whole trees in motion, resistance felt walking against wind
9	41-47	Strong Gale	Slight structural damage occurs, slate blows off roofs

Lesson 1
End of Chapter Assessment

1. What is ecology and why is it important?

2. List and describe the different levels in ecology.

3. Give at least two examples of a testable question that an ecologist might ask. Where do your questions fit within the study of ecology?

4. Name two tools and the abiotic factors they measure in an ecosystem.

5. What types of qualitative or quantitative data would support the conclusion that timber harvest impacts forest nesting birds?

6. To begin research, ecologists will first develop a question they want to investigate. How do they continue their research after they have developed their question? What do they need to do next to finish their research?

7. Which of the following examples describes the relationship between organisms, populations, communities, ecosystems and the biosphere?
    a. Similar organisms form populations, different populations become communities, communities with abiotic factors become an ecosystem and many ecosystems make up the biosphere.
    b. Similar populations form organisms, different organisms become a community, communities with abiotic factors become an ecosystem and many ecosystems make up the biosphere.
    c. The biosphere is made of many communities, many communities with abiotic factors become an ecosystem, ecosystems become populations, different populations become an organism.
    d. None of the above

8. What is resource management's relationship to ecology?
    a. Resource management is the practical application of ecological concepts.
    b. Resource management is a part of ecology, while ecology is a broader idea.
    c. Both resource managers and ecologists study how nature works.
    d. All of the above

9. Which statement describes conservation's role in society?
    a. Conservation practices manage resources for the next generations to have and also use.
    b. Conservation educates the public about ways that they can help Missouri animals.
    c. Conservation educates landowners about the best way to manage ponds.
    d. Conservation practices allow for ecologists to study nature.

10. Compare and contrast Leopold's and Pinchot's idea of conservation in the U.S. What is your definition of conservation?

11. How do people in Missouri benefit from conservation efforts?

Lesson 1
End of Chapter Assessment Scoring Guide

1. What is ecology and why is it important?
   Answer: Ecology is the study of how nature works and includes both abiotic and biotic factors. Ecology is important because it provides our food, clean air, clean water and other natural resources that we need to survive. **(2 points)**

2. List and describe the different levels in ecology.
   Answer: Organism: a single living thing; population: a group of the same organisms; community: a group of populations; ecosystem: a community along with abiotic factors; biosphere: all ecosystems on earth. **(5 points)**

3. Give at least two examples of a testable question that an ecologist might ask. Where do your questions fit within the study of ecology?
   Answer: Sample questions from the text include: How does water temperature affect bullfrog behavior? How many river otters can the Grand River support? How are mink populations affected by muskrat populations? How does flooding affect wetland communities? What role do Missouri wetlands play in shorebird migration?
   Students may not use the sample questions from the text for organisms, populations, communities, ecosystems and the biosphere, but they may model their questions after them. Answers will vary. **(4 points)**

4. Name two tools and the abiotic factors they measure in an ecosystem.
   Answer: Air thermometer measures air temperature; soil thermometer measures soil temperature; sling psychrometer measures humidity; soil moisture meter measures soil moisture; wind meter measures wind speed. **(2 points)**

5. What types of qualitative or quantitative data would support the conclusion that timber harvest impacts forest nesting birds?
   Answer: Population size and nesting success data for each species would show the impacts of timber harvest. Also change of species use of an area (for foraging or other behaviors) could be observed and support conclusions about the impact of the harvest. **(2 points)**

6. To begin research, ecologists will first develop a question they want to investigate. How do they continue their research after they have developed their question? What do they need to do next to finish their research?
   Answer: Research (or an experiment) by ecologists after developing their question includes the basic parts of an experiment such as making a hypothesis, determining independent and dependent variables, setting up a control group and doing the experiment or research with multiple trials. Ecologists may study something very broadly (toward the biosphere level) or more narrowly (at the organism level). They also may use a model to serve as an example in a case in which the study area is too broad or if they are studying the effects of something that might harm plants or animals they are studying. **(2 points)**

7. Which of the following examples describes the relationship between organisms, populations, communities, ecosystems and the biosphere?
   a. Similar organisms form populations, different populations become communities, communities with abiotic factors become an ecosystem, and many ecosystems make up the biosphere.
   b. Similar populations form organisms, different organisms become a community, communities with abiotic factors become an ecosystem and many ecosystems make up the biosphere.
   c. The biosphere is made of many communities, many communities with abiotic factors become an ecosystem, ecosystems become populations, different populations become an organism.
   d. None of the above
   Answer: a **(1 point)**

8. What is resource management's relationship to ecology?
    a. Resource management is the practical application of ecological concepts.
    b. Resource management is a part of ecology, while ecology is a broader idea.
    c. Both resource managers and ecologists study how nature works.
    d. All of the above
    Answer: d **(1 point)**

9. Which statement describes conservation's role in society?
    a. Conservation practices manage resources for the next generations to have and use.
    b. Conservation educates the public about ways they can help Missouri animals.
    c. Conservation educates landowners about the best way to manage ponds.
    d. Conservation practices allow for ecologists to study nature.
    Answer: a **(1 point)**

10. Compare and contrast Leopold's and Pinchot's idea of conservation in the U.S. What is your definition of conservation?
    Answer: Pinchot and Leopold both included humans in their definitions. Pinchot referred to the use of natural resources; whereas, Leopold's definition did not use the word "use" but advocated for balance between humans and the land. Student definitions will vary but could include that conservation is the wise use of natural resources—it keeps them healthy and intact. **(3 points)**

11. How do people in Missouri benefit from conservation efforts?
    Answer: Conservation is important for Missouri citizens (and U.S. and world citizens) because it ensures that we will have natural resources available for us and for future generations. It ensures that we will have trees/forests for products we use, animals for enjoyment and for hunting, etc. **(2 points)**

Lesson 2: Reproduction and Adaptation

Estimated time
(4) 50-minute class periods

Science CLEs

LO.3.A.a   Distinguish between asexual (i.e., binary fission, budding, ~~cloning~~) and sexual reproduction

LO.3.D.a.   Describe the advantages and disadvantages of asexual and sexual reproduction with regard to variation

LO.3.D.c.   Recognize that new heritable characteristics can only result from new combinations of existing genes or from mutations of genes in an organism's sex cells

EC.1.C.b   Predict and explain how natural or human caused changes (biological, chemical and/or physical in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents)

EC.3.B.b   Explain the importance of reproduction to the survival of a species (i.e., the failure of a species to reproduce will lead to extinction of that species)

EC.3.C.a.   Identify examples of adaptations that may have resulted from variations favored by natural selection (~~e.g., long-necked giraffes, long-eared jack rabbits~~) and describe how that variation may have provided populations an advantage for survival

EC3.C.b.   Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance)

EC3.C.c.   Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection

EC.3.C.d.   Given a scenario describing an environmental change, hypothesize why a given species was unable to survive

IN.1.A.a.   Formulate testable questions and hypotheses

IN.1.B.a.   Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., ~~microscopes~~, thermometers, analog and digital meters, computers, ~~spring scales~~, ~~balances~~, metric rulers, ~~graduated cylinders~~)

Vocabulary

Adaptations	Self-incompatible
Reproduction	Genetic homogeneity
Bag limits	Mutation
Asexual reproduction	Recombination
Sexual reproduction	Differential reproduction
Binary fission	Genetic bottleneck
Budding	Inbreeding
Parthenogenesis	Translocation
Vegetative reproduction	Natural selection
Genes	

Objectives

1. Explain the importance of reproduction to the survival of a species.

2. Distinguish between asexual and sexual reproduction and identify species that reproduce asexually, sexually or both.

3. Compare and contrast how traits are passed from parents to offspring in asexually and sexually reproducing organisms.

4. Explain the advantages and disadvantages of asexual and sexual reproduction with regard to variation within a population.

5. Explain how genetic homogeneity may cause a population to be more susceptible to extinction.

6. Explain what causes variation among individuals in a population.

7. Explain the significance of a population's ability to produce more offspring than the environment can support.

8. Explain how environmental factors and variation lead to differential reproduction.

9. Explain how variation affords some individuals a better chance for survival.

10. Describe natural selection.

11. Identify examples of adaptations that may have resulted from variations favored by natural selection.

Resource Management Objectives

1. Explain how bobwhite reproduction affects the management of this game bird.

2. Explain why sexual reproduction is important in the management and restoration of Mead's milkweed.

3. Describe how resource managers are using translocation to increase genetic variation in Missouri's greater prairie-chicken populations.

Essential Questions

1) How is reproduction essential to the continuation of every species?

2) Why is being different essential for survival?

Teacher Notes

Students should read *Nature Unbound* Chapter 2 before beginning Lesson 2 activities.

The schoolyard ecosystem will be used for *Essential Activities 2.1* and *2.2*. Before beginning *Essential Activity 2.1*, have students write prompts in their science notebooks based on Chapter 2 of *Nature Unbound*. The data table provided for *Essential Activity 2.1* may be used as is or modified by students.

Outline of Answers to Objectives

See page 72.

Essential Activities

Essential Activity 2.1—Search for Reproduction
Essential Activity 2.2—Grasshoppers
Essential Activity 2.3—Reproduction, Management and Restoration
Optional Activity 2A—Reproduction
Optional Activity 2B—Adaptations

End of Chapter Assessment

Lesson 2 Questions and Answer Key

Summary

- For a species to continue to exist it must reproduce.
- Organisms reproduce either sexually or asexually.
- Traits are passed from parents to offspring during reproduction.
- Each type of reproduction has advantages and disadvantages.
- Environmental and genetic factors cause variation among individuals in a population.
- Populations produce more offspring than the environment can support.
- Some individuals in a population have a better chance of surviving and reproducing than others in the same population.
- Natural selection causes populations to adapt to their environment over time.
- Adaptations help an organism survive in a particular environment.

Outline of Answers to Objectives

1. **Explain the importance of reproduction to the survival of a species.** (p. 16)
   a. Reproduction is not essential to the survival of individual organisms.
   b. Reproduction is essential, however, to the survival of each population and the species as a whole.
   c. If individual organisms did not reproduce, the population—and the species—would eventually dwindle to nothing. Reproduction is essential for populations and species to continue to exist.

2. **Distinguish between asexual and sexual reproduction and identify species that reproduce asexually, sexually or both.** (p. 17)
   a. Asexual reproduction—it takes only one parent to produce a new organism.
      i. Binary fission
         1. During binary fission a single cell divides into two separate cells, each a separate organism.
         2. Many unicellular organisms, such as bacteria and protists
      ii. Budding
         1. Budding occurs when a mass of cells—the bud—begins growing on the parent's body. When the bud has grown large enough, it breaks off of the parent, forming a new organism.
         2. Hydras, for example
      iii. Parthenogenesis
         1. Parthenogenesis or "virgin birth" occurs when eggs from a female develop into offspring without being fertilized by a male.
         2. Some insects, fish, amphibians and reptiles
      iv. Vegetative reproduction
         1. This occurs when some part of the plant, such as its leaves, roots or stem, breaks off and begins growing into a separate organism.
         2. Many plants including prickly pear
   b. Sexual reproduction—requires two organisms to produce a new organism: eggs from the female and sperm from the male
      i. Most plants and fungi (Some plants including prickly pear can also reproduce asexually.)
      ii. Most fish, amphibians and reptiles
      iii. Birds and mammals

3. **Compare and contrast how traits are passed from parents to offspring in asexually and sexually reproducing organisms.** (p. 18)
   a. Before either type of reproduction occurs, parent organisms make a copy of their DNA.
      i. DNA is the blueprint used to build a new organism.
      ii. Within this blueprint are sections of DNA called genes that give instructions to create specific traits. Every organism has many genes for many different traits.
   b. In asexual reproduction a single parent passes on an exact copy of its genes to its offspring.
   c. In sexual reproduction, offspring have two versions of every gene: one from the mother and one from the father. How the two versions of each gene interact with each other determines the offspring's traits. Only traits with a genetic basis can be passed from parents to offspring. This is true of all organisms.

4. **Explain the advantages and disadvantages of asexual and sexual reproduction with regard to variation within a population.** (p. 19)
   a. Asexual
      i. Advantages
         1. Requires less energy
         2. Can produce offspring at a fast rate
         3. Offspring can colonize new habitats quickly
         4. Offspring can take advantage of temporary resources
      ii. Disadvantages
         1. Offspring are identical to their parents
         2. Many offspring die when environmental conditions change

b. Sexual
   i. Advantages
      1. Offspring are genetically different than their parents.
      2. Genetic variation helps some offspring survive when environmental conditions change.
   ii. Disadvantages
      1. Must have males.
      2. Eggs and sperm must meet.
      3. Forming reproductive organs uses energy.
      4. Courtship uses energy and exposes organisms to injury and predation.

5. **Explain how genetic homogeneity may cause a population to be more susceptible to extinction.** (p. 21)
   a. With genetic homogeneity all the members of the population have similar genes and traits (similar genetic blueprints). The population would be less likely to survive a disease outbreak or a change to its habitat. In other words, genetic homogeneity can be a cause for extinction.

6. **Explain what causes variation among individuals in a population.** (p. 21)
   a. Some variation is caused by environmental factors.
      1. Food is more or less abundant.
         a. With more to eat, some collared lizards might be able to grow longer than collared lizards that live where food is scarce.
      2. Sunlight and water are more or less abundant.
         a. Some of the prickly pears on a glade may be bigger because they live in a sunnier or wetter location than other prickly pears.
   b. Some variation is caused by genetic factors. The genetic blueprint is different for every organism. Each individual's DNA is unique.
      i. Mutation
         1. A mutation occurs when a mistake is made during the copying of DNA, resulting in a genetic blueprint different from the original.
            a. Sometimes mutations cause the new cell to die.
            b. Sometimes mutations have no affect on the new cell.
            c. Sometimes mutations cause the new cell to have traits different from its parent(s).
         2. A mutation can occur in asexually and sexually reproducing populations.
            a. For asexually reproducing populations, mutations are the principal cause of genetic variation for the population.
            b. For sexually reproducing populations, mutations must occur during the formation of sex cells for the mutation to cause variation.
      ii. Recombination
         1. It only occurs in sexually reproducing populations.
         2. Recombination occurs during the formation of eggs and sperm when homologous chromosomes trade genetic information with each other. The eggs or sperm have a genetic blueprint different from the parent.
         3. Genes are mixed and shuffled a second time when a sperm fertilizes an egg to form a new organism.

7. **Explain the significance of a population's ability to produce more offspring than the environment can support.** (p. 22)
   a. Populations produce more offspring than the environment can support.
      i. Environmental factors, such as food shortages and predators, keep populations in check.
      ii. Individuals with traits that help them compete for resources, avoid predators and survive harsh conditions are more likely to live long enough to reproduce.

8. **Explain how environmental factors and variation lead to differential reproduction.** (p. 22)
   a. Differential reproduction occurs in most populations.
      i. When some individuals survive and reproduce at a higher rate than others in the same population, differential reproduction is occuring.
      ii. Other times individuals reproduce at a higher rate because they are able to attract more mates.
      iii. Sometimes individuals reproduce at a higher rate because, like the lichen-colored grasshopper, they are better able to survive in their environment.

9. **Explain how variation affords some individuals a better chance for survival and reproduction.** (p. 22)
   a. Some individuals in a population have a better chance of surviving and reproducing than others in the same population.
      i. Variation may give some individuals a better chance of surviving and reproducing. (*Ex.* Lichen-colored grasshoppers, because of their camouflage that helps them avoid predators, survive better than pink-colored grasshoppers in the same environment.)
      ii. Other individuals reproduce at a higher rate because they are able to attract more mates. (*Ex.* Male prairie-chickens fight each other and do courtship dances for mates.)
   b. When some individuals survive and reproduce at a higher rate than others in the same population, differential reproduction is occurring.

10. **Describe natural selection.** (p. 24)
    a. Natural selection is the process by which organisms become adapted to their environment over time.
    b. Variation + Differential Reproduction + Heredity = Natural Selection.
       i. When some individuals in a population have different traits, variation exists.
       ii. If the trait has a genetic basis, it can be passed from parent to offspring, which is called heredity.
       iii. When individuals possessing the trait survive and reproduce at a higher rate than other individuals in the population, differential reproduction is occurring.
          1. And, if all three of these things happen, natural selection will occur.

10. **Identify examples of adaptations that may have resulted from variations favored by natural selection.** (p. 25)
    a. Over time, natural selection produces adaptations. Every organism has adaptations.
    b. For a trait to be an adaptation, it must help an organism survive in a particular environment, and it must be passed from parent to offspring (genetically based).
    c. Adaptations may be anatomical structures, behaviors or physiological processes.

Resource Management Objectives

1. **Explain how bobwhite reproduction affects the management of this game bird.** (p. 16)
   a. A bobwhite's ability to breed its way back from oblivion has important implications for resource managers.
   b. Quail are a game bird, harvested by hunters for food and sport.
   c. Managing this game bird
      i. Managers regulate bag limits (the number of quail that can be harvested by a single hunter daily), what time of year hunting season occurs and how long hunting season lasts.
      ii. In setting these regulations, managers take into account how many birds may be shot by hunters and how many may die of natural causes.
      iii. As long as hunters leave enough quail to reproduce, the population can recover the following breeding season.

2. **Explain why sexual reproduction is important in the management and restoration of Mead's milkweed.** (p. 20)
   a. The loss of genetic diversity worries resource managers. With few seeds to colonize new prairies, Mead's milkweed populations have little chance of expanding beyond their current locations. With less genetic diversity, adaptation has a harder time keeping up with drastic environmental changes, and small, isolated Mead's milkweed populations are prone to being wiped out.
   b. To prevent the loss of genetic diversity, resource managers are trying several approaches:
      i. Encouraging landowners with Mead's milkweed to delay grazing and haying until mid-September, after Mead's milkweed has dispersed its seeds.
      ii. Asking landowners to avoid spraying pesticides, which kill bees, a primary pollinator of Mead's milkweed.
      iii. Reducing herbicide use in areas where Mead's milkweed occurs.
      iv. Using prescribed fire to stimulate the growth of Mead's milkweed.

3. **Describe how resource managers are using translocation to increase genetic variation in Missouri's greater prairie-chicken populations.** (p. 23)
   a. Translocation involves taking prairie-chickens from thriving populations and releasing them into struggling populations.
   b. During a 5-year period, managers plan to relocate up to 500 prairie-chickens from Kansas to a healthy prairie in southwest Missouri.
   c. Researchers hope this will establish a viable flock and allow biologists to study how well the translocated birds survive and which habitats they use. With success, this could help stop the downward spiral of prairie-chicken populations elsewhere in Missouri.

Essential Activity 2.1
Search for Reproduction

Estimated time
(1) 50-minute class period

Objectives
Students will be able to:
1. Distinguish between asexual and sexual reproduction and identify species that reproduce asexually, sexually or both.

2. Compare and contrast how traits are passed from parents to offspring in asexually and sexually reproducing organisms.

3. Explain the advantages and disadvantages of asexual and sexual reproduction with regard to variation within a population.

4. Explain how genetic homogeneity may cause a population to be more susceptible to extinction.

Teacher Preparation
A large area of the schoolyard ecosystem should be used for this activity. Students will identify organisms within the area and classify them by their method of reproduction. Encourage students to create prompts in their science notebooks as well as record data on the table provided. Students may modify the table if they prefer to organize data differently.

Examples of what students might find outside:

Asexual reproduction examples—Vegetative reproduction: runners from crabgrass, buffalo grass, strawberries, trees re-sprouting from a stump, new willow trees growing from a planted willow stick (also forsythia and other garden plants). Bulbs/tubers: tulips, day lilies. Parthenogenesis: aphids.

Sexual reproduction examples—flowering plants, mammals, most reptiles, most amphibians, birds, most insects, etc.

Materials
Student science notebooks
Pencils
Air thermometer
Nature Unbound student book p. 19
Copies of *2.1 Reproduction Data Table*

Procedure
1. Have students complete their science notebook headings.

2. Hand out copies of *2.1 Reproduction Data Table*.

3. Review pages 16-19 of the student book for examples of reproductive types. Students could place notes on the data sheets.

4. Once outside at the predetermined area, explain boundaries and time limits.

5. Instruct students to:
   a. Search for at least one organism that reproduces asexually, one that reproduces sexually and one that reproduces both asexually and sexually.
   b. Describe what they observe that indicates an organism's method of reproduction. (*Ex*: The flowers of a plant indicate sexual reproduction.) Students may list what they see and return to the classroom to research the answer.
   c. Record one advantage and one disadvantage that each type of reproduction gives each organism observed. (Students may list what they see and return to the classroom to research the answer.)
   d. Keep a list of questions about their observations.

6. At the conclusion of the investigation and data recording, hold the wrap up discussion outside.

Wrap up

1. In what species would you expect to see the most genetic diversity? Why?

2. In what species would you expect to see the least genetic diversity? Why?

3. What is genetic homogeneity? How might it affect a population?

4. List student questions.

5. Discuss which of these questions could be made into testable questions.

6. Create a hypothesis with one of the questions.

Assessment

1. Refer to *Appendix 2: Checklist for Notebooks* on page 214 of the teacher guide.

2. Creation of data table and level of completion.

Extensions

1. Have students search for specific examples of asexual reproduction (such as parthenogenesis or vegetative reproduction).

2.1 Reproduction Data Table

Directions: Find 10 organisms and complete the data table. Organisms may be researched at a later time.

Organism	Type of Reproduction	Indicator (Proof) of Reproduction Method	Advantage	Disadvantage

Essential Activity 2.2
Grasshoppers

Estimated time
(1) 50-minute class period

Objectives
Students will be able to:
1. Explain how environmental factors and variation lead to differential reproduction.

2. Explain how variation affords some individuals a better chance for survival.

Teacher Preparation
Select an area of the schoolyard ecosystem relative in size to the size of the class. This is the study site. Survey the study site in advance:
1. Determine the predominant color of the study site.

2. Obtain golf tees of a color similar to that of the area as well as golf tees of a contrasting color to the area.

3. Count out equal numbers of both colors and spread them randomly over the study site. How far you spread them out depends on how many students you have.

4. Scatter enough golf tees or toothpicks to keep students occupied for at least 10 seconds picking them all up.

Materials
Student science notebooks
Pencils
Air thermometer
Golf tees similar in color to study site
Golf tees contrasting color to study site
Insect collecting nets
Forceps
Collection jars
Magnifiers

Procedure
Part 1
1. Have students complete their science notebook headings.

2. Take students to the predetermined location where the colored golf tees have been distributed and show them an example of each color.

3. Explain that "grasshoppers" in the form of colored golf tees inhabit a specific area of the schoolyard ecosystem.

4. Indicate boundaries of the study site.

5. Have students predict which color of "grasshopper" they expect to capture in greater numbers and record their prediction in their science notebooks.

6. Have students spread out an equal distance from the study site.

7. Explain that once they are given the signal ("Grasshopper!"), they have 10 seconds to collect and bring back as many "grasshoppers" as possible.

8. Give the signal ("Grasshopper!") and count 10 seconds.

9. At the end of 10 seconds, instruct students to stop and return.

10. Have each student count his/her "grasshoppers" and record the number and colors.

11. Have the class add the numbers of each student's sample to create a total population sample for the study site.

12. Have students record the number of each color collected.

13. Have students retrieve the "grasshoppers" that were not collected. Count and record the number of uncollected "grasshoppers" of each color.

14. This is the set that can reproduce. Double this set. (For example, if there were 5 green tees in this set you will add 5 more green tees for a total of 10 and so forth.)

15. Have students face away from the study site and distribute the tees once again.

16. Repeat steps 6 through 10.

17. Have students record their answers in their science notebooks, discuss their findings, and interpret the data.
    a. Were student predictions accurate? Explain why or why not.
    b. Which color "grasshopper" had the better chance to survive and reproduce?

18. What is natural selection? Explain it using the grasshopper activity.

19. What would happen if the habitat changed to a different predominant color?

Part 2
20. Have students use nets and sampling jars to catch and observe real grasshoppers. Depending on the amount of available equipment, students may work alone or in groups; however, each student should have at least one live grasshopper to observe.

21. Have students record the following prompts for grasshopper observations in their science notebooks:
    i.   Sketch the grasshopper.
    ii. Make note of its color and measure its length.
    iii. Describe how it interacts/connects to the plants where it was found.
    iv. Describe the adaptations that help the grasshopper survive.
    v.   List two questions about your grasshopper investigation.

22. At the conclusion of observations, have students return grasshoppers to collection sites.

Wrap up

1. List student questions.

2. Discuss which of these questions could be made into testable questions.

3. How could an experiment be created from these questions?

Assessment

1. Refer to *Appendix 2: Checklist for Notebooks* on page 214 of the teacher guide.

Extensions

1. Have students research the natural history of grasshoppers—species, habitats, reproduction, life cycle, predators, etc.

2. Have students create an experiment from one of the testable questions.

Essential Activity 2.3
Reproduction, Management and Restoration

Estimated Time
(2) 50-minute class periods (or homework)

Objectives
Students will be able to:
1. Explain how genetic homogeneity may cause a population to be more susceptible to extinction.

2. Explain the significance of a population's ability to produce more offspring than the environment can support.

3. Explain how environmental factors and variation lead to differential reproduction.

4. Identify examples of adaptations that may have resulted from variations favored by natural selection.

Note: To meet objectives 5, 6, and 7 students must share their work.
5. Explain how bobwhite reproduction affects the management of this game bird.

6. Explain why sexual reproduction is important in the management and restoration of Mead's milkweed.

7. Describe how resource managers are using translocation to increase genetic variation in Missouri's greater prairie-chicken populations.

Teacher Preparation
This activity may be done during class time or used as a homework assignment. This could be a small group activity.

Materials
Nature Unbound student book
    Ecology in Action – Giving Bobwhite Reproduction a Boost, pp. 16-17
    Ecology in Action – Mead's Milkweed, p. 20
    Ecology in Action – Greater Prairie-Chicken Translocation, p. 23
Internet access
Missouri Department of Conservation website: www.mdc.mo.gov

Procedure

1. Assign or have students choose one of the Ecology in Action articles from Chapter 2 of *Nature Unbound*.

2. Have students research and prepare a report or PowerPoint on their selected species.

3. Reports should include:
   a. Habitat requirements of the species
   b. Adaptations of the species (including reproductive factors)
   c. Challenges faced by the species
   d. Methods being used by scientists and biologists to meet these challenges and increase the genetic diversity of the population
   e. Reasons why students think the species will or will not survive.

4. Have students present their PowerPoint or report to the class.

Wrap up

1. Discuss how reproduction affects species' survival.

Assessment

1. Refer to *Appendix 3: Scoring Guide for Oral Presentation* on page 215 of the teacher guide.

Extensions

1. Have students research other Missouri species and identify their reproductive success or lack of reproductive success.

Optional Activity 2A
Reproduction

Estimated time
(2) 50-minute periods

Objectives
Students will be able to:
1. Explain the importance of reproduction to the survival of a species.

2. Distinguish between asexual and sexual reproduction.

3. Describe examples of different kinds of asexual reproduction.

4. Identify species that reproduce asexually, sexually or both.

5. Compare and contrast how traits are passed from parents to offspring in asexually and sexually reproducing organisms.

6. Explain the advantages and disadvantages of asexual and sexual reproduction with regard to variation within a population.

7. Explain how bobwhite reproduction affects the management of this game bird.

8. Explain why sexual reproduction is important in the management and restoration of Mead's milkweed.

Teacher Preparation
In this activity, students review the difference between asexual and sexual reproduction (or organisms that have the ability to do both). Review the difference between asexual and sexual reproduction (but focus more on the genetics). Remind students that both types are considered to be reproduction that can support the definition of species.

Students will be asked to come up with examples of organisms that reproduce asexually, organisms that reproduce sexually or organisms that use both types of reproduction. *Note*: Viruses have their own type of reproduction, as well as some characteristics that make them questionable as a living thing, and are not a good example here. Student understanding of the genetics of reproduction is important.

Materials
Student science notebooks
Pencils
Nature Unbound student book
Web resources

Procedure

Part 1

1. Have students complete their science notebook headings.

2. In their science notebooks, have students write the definition for species in their own words and provide at least one example.

3. Have students list organisms that fit the definition. Encourage students to list organisms other than plants and animals. Accept any/all answers that fit the definition.

4. Review asexual and sexual reproduction.

Part 2

1. In the student book, have students reread Ecology in Action sections "Giving Bobwhite Reproduction a Boost" (pp. 16-17) and "Mead's Milkweed" (p. 20) to see how reproduction information is applied in the resource management field.

2. Questions for discussion:
   - What might you do to create more quail habitat?
   - How would you work with landowners to make changes to encourage quail habitat areas or to increase the number of Mead's milkweed plants?

Wrap up

1. Have students answer the following questions in their science notebook:
   a. What happens if reproduction of a species does not occur?
   b. What is the importance of reproduction to the survival of a species?
   c. What is the advantage of an organism that can reproduce either asexually or sexually?
   d. Would a population of offspring from asexual reproduction or a population of offspring from sexual reproduction have more variation (or differences) among offspring?

2. Have students share and discuss their answers.

Assessment

1. Explain one advantage of asexual reproduction and one advantage of sexual reproduction as each relates to genetic variation. Explain one disadvantage of asexual reproduction and one disadvantage of sexual reproduction as each relates to genetic variation.

   Answer: (4 points possible, 1 point for each correct advantage or disadvantage provided)

   Asexual

       Advantages
   1. Requires less energy
   2. Can produce offspring at a fast rate
   3. Offspring can colonize new habitats quickly
   4. Offspring can take advantage of temporary resources

       Disadvantages
   1. Offspring are identical to their parents
   2. Many offspring die when environmental conditions change

   Sexual

       Advantages
   1. Offspring are genetically different than their parents
   2. Genetic variation helps some offspring survive when environmental conditions change

       Disadvantages
   1. Must have males
   2. Eggs and sperm must meet
   3. Forming reproductive organs uses energy
   4. Courtship uses energy and exposes organisms to injury and predation

Optional Activity 2B
Adaptations

Estimated time
(1) 50-minute period

Objectives
Students will be able to:
1. Identify examples of adaptations that may have resulted from variations favored by natural selection.

Teacher Preparation
Students will explore adaptations by creating an animal for a specific environment. Students may work alone or in pairs. Animals can be drawn and described on paper, but students are to create a model animal. Have students create their animals from recycled materials or natural items from the schoolyard ecosystem. Establish guidelines for natural items students may/may not collect (*Ex*: collect only loose items on the ground; collect only small pieces of certain trees or plants; do not collect anything that must be cut or broken off a plant).

Students may stay within the confines of animal classification (*Ex*: mammal, reptile, arthropod) but should create a totally new animal.

Materials
Student science notebooks
Pencils
Web access
Miscellaneous natural, recycled, craft, etc. items for creating animal models

Procedure
1. Have students pick a Missouri habitat for their animal. They should research the physical and biological aspects of the habitat they have chosen.

2. Explain that they are going to make a model of an original animal that illustrates specialized features and behaviors (adaptations) that would help it survive in the chosen habitat.

3. Decide what their animal would look like and sketch a picture of the animal in their science notebooks.

4. Brainstorm what criteria need to be met. Have students describe the animal's behavior, including the way it obtains food and water, the kind of dwelling in which it lives, its reproductive process, its defensive behavior, and how it moves and gets oxygen, etc. in their science notebooks.

5. Remind students that they should not just copy a real wild animal but create an original one—the stranger the better as long as it has adaptations suited to surviving in their chosen habitat.

6. Have students create their animal models.

7. Have students name their animal using proper scientific nomenclature (*Genus* and *species*).

8. Have the students share their animals with the rest of the class.

Wrap up

1. Have students debate which animals would survive.

2. What, if any, adaptations were common to all created animals? Why?

Assessment

1. See the *Scoring Guide for Model of Created Animal* on next page.

2. Check science notebook pages for completion and accuracy.

Extensions

1. Create a computer model of the animal.

2. Create a storyboard, illustrated story, or cartoon of the animal that shows how it would survive.

3. Create or modify a dichotomous key to identify the animal(s).

4. Have students go on a nature walk to collect natural items to be used in creating the animal. Ask students to think about the shape and contour of the animal so they can search for items in nature that can be used to replicate the shape.

Scoring Guide for Model of Created Animal

	4	3	2	1	0
Model	Complete with model showing 5 or more adaptations to the habitat	Model with 4 adaptations	Model with 2-3 adaptations	Incomplete model showing only 1 or no adaptations	No model
Reasoning	Complete explanation of all adaptations	Complete explanation of some of the adaptations	Incomplete explanation of some of the adaptations	Incorrect explanation	No explanation
Environment	Complete physical and biological description of the chosen habitat	Partially incomplete physical and biological description of the chosen habitat	Incomplete physical and biological description of the chosen habitat	Incorrect description	No description

Lesson 2
End of Chapter Assessment

1. Why is reproduction important to the survival of a species?

2. Which selection below is an example of asexual reproduction?
    a. Reproduction in which offspring are genetically different than their parents
    b. Vegetative reproduction—for example, the runners produced by buffalo grass which spread and grow new plants
    c. The process of replicating a compact disk
    d. Self-incompatible

3. Complete the chart below.

Organism	Sexual Reproduction	Asexual Reproduction	Both
Example: Hydra			✓
Common milkweed			
Bald Eagle			
Elk			
Bacteria			
Prickly pear cactus			
Rabbit			
Bolete mushroom			

4. Compare and contrast asexual and sexual reproduction in regard to how traits are passed from parents to offspring.

5. Bobwhite quail are efficient at reproduction, and females have the ability to lay many eggs in a breeding season. Despite this, they are not always successful as a species. What other considerations have to be made when resource managers decide how to set the quail hunting season?

6. What factors make Mead's milkweed particularly rare in Missouri?
    a. Mead's milkweed requires an old growth forest habitat.
    b. Mead's milkweed reproduces asexually and requires a prairie habitat.
    c. Mead's milkweed requires a prairie habitat and is self-incompatible.
    d. Mead's milkweed requires a prairie habitat and mammal pollinators.

7. Genetic homogeneity is the situation that occurs when members of a population have very similar genetic information. How could this lead to extinction of a species?

8. Identify and describe two causes of genetic variation in organisms of a population.

9. How is variation in a population important for survival of the population?

10. Natural selection can be described by using the following equation:
    Variation + Differential Reproduction + Heredity = Natural Selection
    What does each part mean, and how do the parts of the equation go together to explain natural selection?

11. Fill in the chart below.

Organism	Adaptation	Describe how this benefits the organism
Example: *Lichen-colored grasshopper*	Coloration/camouflage	Helps the organism survive by allowing it to hide from predators
Box turtle		
	Gills	
		Attracts insect pollinators
Blackberry plant		

12. How is the method of translocation helping Missouri's prairie-chicken populations?

Lesson 2
End of Chapter Assessment Scoring Guide

1. Why is reproduction important to the survival of a species?
   Answer: Reproduction is important to the survival of a species by making sure the population grows so there are plenty of organisms. **(1 point)**

2. Which selection below is an example of asexual reproduction?
   a. Reproduction in which offspring are genetically different than their parents
   b. Vegetative reproduction—for example, the runners produced by buffalo grass which can spread and grow new plants
   c. The process of replicating a compact disk
   d. Self-incompatible
   Answer: b **(1 point)**

3. Complete the chart below. **(7 points)**

Organism	Sexual Reproduction	Asexual Reproduction	Both
Example: Hydra			✓
Common Milkweed			✓
Bald Eagle	✓		
Elk	✓		
Bacteria		✓	
Prickly pear cactus			✓
Rabbit	✓		
Bolete mushroom			✓

4. Compare and contrast asexual and sexual reproduction in regard to how traits are passed from parents to offspring.
   Answer: Asexual reproduction involves one parent, and the traits passed to offspring are identical to the parent's traits, unless a genetic mutation occurs. Sexual reproduction involves two parents and the traits passed are a combination of the both parents' genes or are due to genetic recombination of the genes during sex cell formation. Both forms of reproduction pass genetic traits from a parent organism to its offspring. **(2 points)**

5. Bobwhite quail are efficient at reproduction, and females have the ability to lay many eggs in a breeding season. Despite this, they are not always successful as a species. What other considerations have to be made when resource managers decide how to set the quail hunting season.
   Answer: Resource managers have to remember that many quail die because they become food for other organisms, and their habitat needs are great. Even though there are many eggs laid each year, their mortality rate is very high. Resource managers must also consider how many quail may be harvested by hunters when setting the quail hunting season. **(2 points)**

6. What factors make Mead's milkweed particularly rare in Missouri?
   a. Mead's milkweed requires an old growth forest habitat.
   b. Mead's milkweed reproduces asexually and requires a prairie habitat.
   c. Mead's milkweed requires a prairie habitat and is self-incompatible.
   d. Mead's milkweed requires a prairie habitat and mammal pollinators.
   Answer: c **(1 point)**

7. Genetic homogeneity is the situation that occurs when members of a population have very similar genetic information. How could this lead to extinction of a species?
    Answer: If all members of a species have the same genetic makeup, they are more susceptible to dying off due to environmental conditions. If they all have a similar genetic weakness, for example, they may not be able to fend off a disease. **(2 points)**

8. Identify and describe two causes of genetic variation in organisms of a population.
    Answer: Genetic variation can occur in three ways:
    1. Genetic factors—Mutations are a slight error in copying of the DNA. A specific mutation may actually be more favorable for an organism.
    2. Genetic factors—Recombination occurs when homologous chromosomes trade genetic information with each other. Genes are then mixed a second time when sperm fertilizes an egg to form a new organism. **(1 point for each part answered correctly, 2 points possible)**

9. How is variation in a population important for survival of the population?
    Answer: More variation in a population means that something like an environmental disruption will be less damaging to the overall population—some may die, but not all. **(1 point)**

10. Natural selection can be described by using the following equation:
    Variation + Differential Reproduction + Heredity = Natural Selection
    What does each part mean, and how do the parts of the equation go together to explain natural selection?
    Answer: Natural selection relies on variation (the idea that organisms in a population have different traits). These traits, along with differential reproduction (the idea that some organisms will survive and reproduce more often in a population) and heredity (the genetic traits passed on to offspring) equate to natural selection (the process by which organisms become adapted to their environment over time). **(4 points total, 1 point for each correct part)**

11. Fill in the chart below. **(8 points)**

Organism	Adaptation	Describe how this benefits the organism
Example: Lichen-colored grasshopper	Coloration/camouflage	Helps the organism survive by allowing it to hide from predators
Box turtle	**Shell**	**Protection from predators**
Bluegill (or other fish or aquatic insect)	Gills	**Collect oxygen from the water**
Sunflower	**Colorful flower**	Attracts insect pollinators
Blackberry plant	**Thorns**	**Protection from herbivores**

12. How is the method of translocation helping Missouri's prairie-chicken populations?
    Answer: Translocation is helping Missouri prairie-chicken populations by creating more genetic variation. Moving new birds to join Missouri's populations will keep the entire population stronger by introducing different genes into existing populations. **(1 point)**

Lesson 3: Population Checks and Balances

Estimated time
(4) 50-minute class periods

Science CLEs

EC.1.B.a. Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem

EC.3.C. Natural selection is the process of sorting individuals based on their ability to survive and reproduce within their ecosystem

EC.3.C.b. Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance)

EC.3.C.c. Exlain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection

IN.1.A.a. Formulate testable questions and hypotheses

IN.1.A.b. Analyzing an experiment, identify the components (i.e., independent variable, dependent variables, control of constants, multiple trials) and explain their importance to the design of a valid experiment

IN.1.A.c. Design and conduct a valid experiment

IN.1.B.a. Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., ~~microscopes~~, thermometers, analog and digital meters, computers, ~~spring scales~~, ~~balances~~, metric rulers, ~~graduated cylinders~~)

IN.1.C.a. Use quantitative and qualitative data as support for reasonable explanations (conclusions)

IN.1.C.b. Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable)

Vocabulary

Population size
Population density
Dispersion
Mark-recapture methods
Lincoln-Peterson estimate
Census
Sample
Quadrats
Transects
Immigration
Emigration

Exponential growth
Per capita rate of growth
Life table
Limiting factors
Density-independent factors
Density-dependent factors
Compensatory mortality
Additive mortality
Carrying capacity
Cultural carrying capacity

Objectives

1. Describe the different ways ecologists measure populations.

2. Explain what causes populations to increase or decrease.

3. Explain how populations grow in the presence of abundant resources.

4. Predict how a population's size might change over time.

5. Define limiting factor and list examples.

6. Explain how limiting factors affect populations by changing birth and death rates.

7. Compare and contrast density-dependent and density-independent limiting factors.

8. Explain how carrying capacity affects population growth.

Resource Management Objectives

1. Describe ways resource managers sample populations.

2. Explain how scientists use mark-recapture methods to estimate population size.

3. Explain how a species' life history affects resource management decisions.

4. Compare and contrast compensatory and additive mortality.

5. Compare and contrast biological and cultural carrying capacity.

Essential Questions

What keeps any species from overrunning the earth?

Teacher Notes

Students should read *Nature Unbound* Chapter 3 before beginning Lesson 3 activities.

These activities require prior set up. Students will utilize population sampling techniques and explore factors that affect population size.

Outline of Answers to Objectives

See page 98.

Essential Activities

Essential Activity 3.1—Mark and Recapture: A Method of Estimating Populations
Essential Activity 3.2—How do Scientists Know?
Essential Activity 3.3—Elk in Missouri
Optional Activity 3A—Mark and Recapture: Alternative Method

End of Chapter Assessment

Lesson 3 Questions and Answer Key

Summary

- Ecologists measure populations in different ways.
- Births and deaths cause populations to grow and shrink.
- With abundant resources, populations can grow quickly.
- Many factors limit how large a population can grow.
- Some limiting factors affect growth regardless of the population's density; other limiting factors affect growth in relation to the population's density.
- Population growth slows as population size nears carrying capacity.

Outline of Answers to Objectives

1. **Describe the different ways ecologists measure populations.** (p. 28)
   a. One measurement is population size or the number of individuals making up the population.
   b. Another is population density or the number of individuals per unit area.
   c. Another is dispersion which is the spacing of individuals in a population. Populations can be dispersed in a clumped, uniform or random pattern.

2. **Explain what causes populations to increase or decrease.** (p. 32)
   a. Four factors affect population size: births, deaths, immigration and emigration.
   b. For most populations, births and deaths affect population size more than immigration or emigration.
   c. When there are more births than deaths, the population grows.
   d. When there are more deaths than births, the population shrinks.

3. **Explain how populations grow in the presence of abundant resources.** (pp. 32-33)
   a. With abundant resources—food, space, nesting sites—populations grow slowly at first and then faster and faster. If we were to plot this kind of growth on a graph, it would make a J-shaped curve.
   b. Reproduction causes the population to increase by multiplication rather than addition.
   c. This type of growth is called exponential growth.

4. **Predict how a population's size might change over time.** (p. 34)
   a. The population size in one year is the current population size multiplied by the per capita growth rate.
   b. If we want to estimate the population size at three years, we could perform the calculation three times.
   c. Since birth and death rates vary with ages of individuals in the population, per capita growth rate can be determined for each age class (called a life table) to provide a more accurate estimate.

5. **Define limiting factor and list examples.** (p. 35)
   a. Limiting factors are those factors that slow a population's growth or prevent it from existing in certain areas.
   b. Examples will vary but could include abiotic factors like sunlight, temperature, nutrients or precipitation. Biotic factors might include predators, competition, availability of food, shortage of mates, outbreak of disease or infestation of parasites.

6. **Explain how limiting factors affect populations by changing birth and death rates.** (p. 36)
   a. When there are few limiting factors, births increase and deaths decrease.
   b. When there are many limiting factors, births decrease and deaths increase.

7. **Compare and contrast density-dependent and density-independent limiting factors.** (p. 36)
   a. Density-independent factors affect a population regardless of its density.
   b. Density-dependent factors affect a population in ways related to population density.

8. **Explain how carrying capacity affects population growth.** (p. 38)
   a. Most populations hover around carrying capacity.
   b. When a population grows larger than carrying capacity, there aren't enough resources and deaths outnumber births, bringing the population size back to carrying capacity.
   c. When a population shrinks smaller than carrying capacity, there are more than enough resources and births outnumber deaths, bringing the population size back to carrying capacity.

Resource Management Objectives

1. **Describe ways resource managers sample populations.** (p. 30)
    Resource managers sample populations in many ways. Sometimes they divide a large area into smaller sections called quadrats and count all individuals in some quadrats. Other times they walk straight lines of known length called transects and count individuals. They also count nests, scat, hair or other evidence left behind.

2. **Explain how scientists use mark-recapture methods to estimate population size.** (p. 29)
    Mark-recapture involves catching a sample of the population and marking the captured individuals in some way (paint, leg band, ear tag, etc). Individuals are then released and allowed to mix back into the population. After time, a second sample is captured. By comparing the number of individuals marked in the first sample to the marked individuals in the second sample, scientists can estimate the population size.

3. **Explain how a species' life history affects resource management decisions.** (p. 37)
    Resource managers use what they know about population changes to provide valuable scientific input to rule makers when setting hunting seasons, bag limits and harvest methods for populations.

4. **Compare and contrast compensatory and additive mortality.** (p. 37)
    With compensatory mortality the different causes of death balance out or compensate for each other. In additive mortality the different causes of death add to each other.

5. **Compare and contrast biological and cultural carrying capacity.** (p. 39)
    Biological carrying capacity is the number of individuals the habitat will support at a given time. The cultural carrying capacity is the number of individuals that people will tolerate.

Essential Activity 3.1
Mark and Recapture: A Method of Estimating Populations

Estimated time
(2) 50-minute class periods

Objectives
Students will be able to:
1. Describe the different ways ecologists measure populations.

2. Describe the ways resource managers sample populations.

3. Explain how scientists use mark-recapture methods to estimate population size.

Teacher Preparation
This activity is based on isopods (roly-polies). If none are found in the schoolyard ecosystem, crickets (purchased from a bait shop), grasshoppers or another organism that populates the schoolyard ecosystem may be substituted.

Prior to teaching this activity, locate an area in the schoolyard ecosystem that contains rocks and/or fallen logs large enough to provide habitat for isopods but small enough for students to turn over. Check for the presence of isopods under several rocks or logs in the area. Locate enough rocks/logs to provide one rock/log per group of 3-4 students. Each group will work with one rock/log during the first sampling period and note its location carefully enough to be able to find it for the second sampling period.

Have students work in groups of 3-4 and provide one copy of the *Isopod Mark and Recapture Instructions* sheet (laminated, if possible) per group. Students will use the Lincoln-Petersen estimate found on page 29 of *Nature Unbound*.

$$N = \frac{n_1 n_2}{m_2}$$

Materials
Student science notebooks
Pencils
Air thermometer
Containers/trays—1 per group
Colored nail polish—1 per group
(Laminated) Copies of *Isopod Mark and Recapture Instructions*—1 per group

Procedure
Sampling Period #1
1. Have students complete their science notebook headings, record a description of their sampling site and be prepared to record questions they have during the sampling.

2. At the predetermined area, distribute containers, nail polish and *Isopod Mark and Recapture Instructions* to each group.

3. Have each group stand next to one of the chosen rocks/logs and instruct them to follow directions on the instructions sheet.

Sampling Period #2 [2-3 days later]

4. Have students complete their science notebook headings and be prepared to record questions they have during the sampling.

5. Return to the same sampling area and distribute containers, nail polish and *Isopod Mark and Recapture Instructions* to each group.

6. Have each group locate their original rock/log and instruct them to follow directions on the instructions sheet.

7. Have students record the population estimate in their science notebook.

8. Have each group share their population estimate for the sampled rock/log.

Wrap up

1. Discuss student findings and observations and create a class chart.

2. Have the students review the class data and postulate the reasons for differences in the groups' results.

3. Would they be able to estimate the population size of isopods for the entire schoolyard ecosystem? Explain.

4. What are the pros and cons of this sampling technique? Consider accuracy, harmful effects on a population, etc.

5. Review the assumptions of this method (p. 29 of *Nature Unbound*).

6. Compile a list of questions that can be created from the data collected.

7. From that list, write a testable question and hypothesis.

8. Identify the dependent and independent variables.

Assessment

Check student science notebooks for completion and accuracy.

Extensions

1. Have students research the natural history of isopods (species, habitats, reproduction, life cycle, etc.).

2. Have students create an experiment or field study from one of the testable questions.

3. Encourage students to participate in Monarch Watch (www.monarchwatch.org) and to record their data on Google Earth (www.google.com/earth/index.html).

3.1 Isopod Mark and Recapture Instructions

Materials
Student science notebooks
containers
nail polish

Directions: Follow the instructions below.

Sampling Period #1
1. Select a rock/log from the study site.

2. Note and describe the location of the rock/log as accurately as possible in your science notebook. (This will be the same rock/log used during Sampling Period #2.)

3. Carefully turn over the rock/log and collect as many isopods as possible and place them into the container.

4. Carefully place a small dot of nail polish on the back of each of the captured isopods.

5. One person in each group should record how many isopods are marked.
   [This number represents n1, the number of individuals marked and released in the first sample.]

6. After the nail polish is dry, return the marked isopods to the original location and carefully replace the rock/log.

7. Return containers, nail polish and this instruction sheet.

Sampling Period #2
1. Locate the original rock/log from Sampling Period #1.

2. Carefully turn over the rock/log and collect as many isopods as possible and place them into the container.

3. Count the total number of captured isopods.
   [This number represents n2, the total number of individuals captured in the second sample.]

4. Count marked isopods captured.
   [This number represents m2, the number of individuals with marks in the second sample.]

5. Return all marked and unmarked isopods to the original location and carefully replace the rock/log.

6. Return containers, nail polish and this instruction sheet.
   Complete the Lincoln-Petersen estimate.

$$N = \frac{n_1 n_2}{m_2}$$

7. What is the population estimate for the sampled rock/log?

NATURE UNBOUND: THE IMPACT OF ECOLOGY ON MISSOURI AND THE WORLD

Essential Activity 3.2
How Do Scientists Know?

Estimated Time
(1) 50-minute class period

Objectives
Students will be able to:
1. Describe the different ways ecologists measure populations.

2. Describe ways resource managers sample populations.

Teacher Preparation
For this activity, students will sample a population. Divide the class into six groups. Have students review the "Ecology in Action" section of *Nature Unbound* (pp. 30-31). To successfully sample an area, scientists must have an idea of what population is there in the first place and how that population changes over time. Often an area is too large, or it is impractical to count every individual, so a sample is taken and then used to extrapolate the population of an area or site. There are several ways to do this, but **for this activity, students will use a "picture in time"** as the sampling method (items sampled are not mobile). Students will count individuals in a particular area at a point in time. Students will use the **ratio/proportion** method to calculate the population size.

$$\frac{\text{Total \# animals in sample \_\_\_\_}}{\text{Total \# animals in study site (x)}} = \frac{\text{Area sampled \_\_\_\_}}{\text{Total area of study site}}$$

For example, if there were 10 deer in the sample:

$$\frac{\text{Total \# animals in sample (10 deer)}}{\text{Total \# animals in study site (x)}} = \frac{\text{Area sampled (30 Ac.)}}{\text{Total area of study site (150 Ac.)}}$$

$$\frac{10}{x} = \frac{1 \text{ acre}}{5 \text{ acre}}$$

10 deer x 5 Ac. / 1 Ac. = 50 deer estimated in study site.

The study site must be set up in advance:
1. Outline the study area by placing a rope exactly 42 feet 8 inches long in a square each side of which should be 10 feet 8 inches long. It is important to lay the rope out as squarely as possible. Place an orange cone or tent stake at each corner to hold the rope in place.

2. Randomly and (fairly evenly) spread all the golf tees within the square study site.

3. Randomly place the hula hoops numbered 1-6 into the square study site. Hula hoops should not overlap or extend onto or outside the square.

4. Hula hoops represent quadrats. *Note*: Arrange hula hoops to allow enough space for each group to gather around the outside of their chosen hula hoop.

Materials

Student science notebooks
Nature Unbound student book
Pencils
Air thermometer
Orange cones or tent stakes (4)
Rope—exactly 42' 8" long
Bag of golf tees (75 blue, 100 white, 75 red, 25 tan)
Hula hoops—numbered 1 through 6
Copies of *3.2 Data Sheets*—one per group
Easel and flip chart
Markers
Calculators

Procedure

1. Have students complete their science notebook headings.

2. Divide students into six groups and give each group a *3.2 Data Sheet*.

3. At the study site, explain that students will use a sampling technique called a "picture in time," that they will calculate a population size by using a ratio/proportion method and that with this method, they should assume:
   • The population is not very mobile.
   • The population is equally dispersed over the study area.
   • Every individual has an equivalent chance of being counted.

Note: Students must not move the golf tees. This is a visual sampling of a population and not a mark and recapture sample.

4. Each group should choose its own quadrat (hula hoop), count the number of individuals (golf tees) of each type (color) and record the information on the Data Sheet using the golf tee color key on the *3.2 Data Sheet*.

5. Have students add the number of each species in the samples and total the columns. For the purposes of this activity, inform students that the entire study site is 150 acres (60.71 hectares) and that each hula hoop represents 5 acres.

6. Analysis
   a. The number of individuals in the quadrats should be proportional to the number of individuals in the entire study site.
   b. If the entire study site is 150 acres (60.71 hectares) and each quadrat (hula hoop) represents 5 acres, how many acres have been sampled? [30 acres or 12.14 hectares]
   c. Insert sample numbers into the formula below and calculate the estimated populations for each species:

$$\frac{\text{Total \# animals in sample} \_\_\_\_\_}{\text{Total \# animals in study site (x)}} = \frac{\text{Area sampled} \_\_\_\_\_}{\text{Total area of study site}}$$

7. Complete calculations for all samples.

8. Have students collect the golf tees, hula hoops and rope.

Wrap up

1. Provide students with the actual numbers of populations and have them compare their population estimates with the actual population numbers.

   Coyote – 25   Turkey – 75
   Deer – 100   Quail – 75

2. What could account for any differences? Review the assumptions:
   - The population is not very mobile.
   - The population is equally dispersed over the study area.
   - Every individual has an equivalent chance of being counted.

3. Are these accurate assumptions based on the species selected? Why or why not?

4. What method could be used to provide a more accurate assessment of the population without adding work?

5. Why would an area manager or landowner want to know or even care about the wildlife populations on an area or on his/her property?

6. Why would an ecologist need to have an accurate idea of the size of a population?

Assessment

Check Data Sheet and formula calculations for completion and accuracy.

Extensions

1. Set up a study plot to estimate the population size of a species in the schoolyard ecosystem.

3.2 Data Sheet

Site Number _____

Directions: Count individuals within the quadrat (hula hoop) and place the number in the corresponding box. When all data have been placed on this sheet, add this data to the Sample Summary Chart below.

Coyote (tan) _____ Deer (white) _____ Quail (blue) _____ Turkey (red) _____

Population Estimates

Sample Summary Chart

Directions: Enter all data from each group. Calculate the formula below.

Site Number	Number of Animals in Each Hula Hoop			
	Coyote	Deer	Quail	Turkey
1				
2				
3				
4				
5				
6				
Total (Sums)				
Population Estimate				

Total # animals in sample

_____ = _____

Total # animals in study site

(Also called population estimate)

Area sampled (30 Ac.)

Total area of study site (150 Ac.)

Essential Activity 3.3
Elk in Missouri

Estimated Time
(1) 50-minute class period

Objectives
Students will be able to:
1. Explain the concept of limiting factors.

2. Explain what causes populations to increase or decrease.

3. Explain how populations grow in the presence of abundant resources.

4. Predict how a population's size might change over time.

5. Explain how carrying capacity affects population growth.

6. Describe the relationship between elk populations, their food supplies and predators including hunters.

7. Predict how changes in ecosystems will affect elk populations.

8. Recognize that conservation can involve the harvesting of a natural resource in a way that ensures the continuing availability of that resource.

Teacher Preparation
Prior to this activity, provide students with and have them read the *Elk Information Sheet* or have them research the natural history of elk.

Elk, like all wildlife, have basic needs that their habitat must provide. Elk are herbivores, consuming predominantly herbaceous plants like grasses and forbs (broadleaf vegetation). They feed by grazing slowly across the landscape. They will also eat browse, or woody vegetation such as tree bark and twigs. An elk's diet will vary depending on the size of the animal and availability of food in the habitat. When in short supply, food can be a limiting factor (impacting the survival of the animals). This active simulation allows students to discover some of the limiting factors that may affect the survival of elk. Refer to the *Elk Information Sheet* for additional information regarding elk.

Refer to the table on the next page regarding the food requirements of an average adult elk for 3 fall months. Gather the correct number and color of tokens to represent the amount of food needed for a class of 30 students to play the game. Mark the 3 colors of tokens with an A and B to represent varying quality of the available food. Adjust the number of tokens to the group size so that there are fewer than 1,350 pounds available per student.

Fall Requirements Per Animal

Token Color	% of Diet	Requirements per 3 Months of Fall	Tokens Required for 30 Students
Grasses (green tokens)	40%	540 lb.	15 = 450 lb. each (A) 45 = 200 lb. each (B)
Broadleaf Forbs (yellow tokens)	25%	340 lb.	15 = 270 lb. each (A) 45 = 135 lb. each (B)
Browse (brown tokens)	35%	470 lb.	15 = 350 lb. each (A) 45 = 200 lb. each (B)
Total	**100%**	**1,350 lb.**	**180 Tokens**

Materials

Copies of *Elk Information Sheet*—one per student (to be read prior to this activity)
Student science notebook
Pencils
Copies of *3.3 Tally Sheet*—one per student
180 tokens (60 tokens of 3 different colors to represent grasses, forbs and browse)
Sandwich or other bags for students to collect tokens

Procedure

1. Review natural history of elk.

2. Review concepts of habitat and carrying capacity.

3. Provide students with *3.3 Tally Sheet.*

4. Play the Missouri Elk Game using the food tokens.
   a. For a class size of 30, 180 food tokens of 3 colors will be used.
   b. Randomly place the various food tokens in the space selected for the activity.
   c. Remind students that elk browse for food. To simulate this behavior, students must move slowly.
   d. The goal is for each elk to survive 3 months, or a fall season. Each elk requires approximately 1,350 pounds or 630 kilograms of various food components to survive one fall season. Do not tell students what the token colors or letters on the tokens represent. Instruct students to gather different kinds of food to represent a variety of food in the elk's diet. Students should pick up tokens one at a time and use sandwich bags to collect tokens until each round is completed.
   e. Have students count off from 1 to 4 so that they are divided into four groups. Eventually each student will participate, but only ½ the group will participate in the first round. For the first round, have students numbered 3 and 4 sit and watch. Those students can assist with tabulating tokens and recording data.
   f. Round 1—Small population, fixed food supply. This simulates the first year when the elk population is small and food is readily available. Have students attempt to collect enough food to survive the first fall, or approximately 1,350 pounds of the various food components.
      i. Give students numbered 1 and 2 approximately 5 minutes to collect food tokens.
      ii. Have the students tabulate the amount of food they collected.
      iii. Record the number of elk that collected at least 1,350 pounds of food and survived.
      iv. Discussion:
         • How many elk survived? Why?
         • Could the habitat support more elk? Why or why not?
      v. Have students replace the tokens in the selected area for Round 2.

g. Round 2—Large population, fixed food supply. This simulates 5 years after Round 1. Reproduction among the survivors produced additional elk, but the fall food supply remains the same.
   i. Have all students participate in Round 2.
   ii. Give students 5 minutes to collect food for the fall season.
   iii. Have students tabulate the pounds they collected.
   iv. Record the number of elk that survived.
   v. Discussion:
     • How many students were able to collect 1,350 pounds of food? Why or why not?
     • What would happen to the remaining elk?
     • Was the carrying capacity of the habitat reached?
   vi. Have students replace the tokens for Round 3.

h. Round 3—Reduced population, fixed food supply with hunters as predators. This simulates 5 years later. Reproduction among the survivors has caused the elk population to increase, which produces a surplus of elk. Find out what happens when hunters act as predators to reduce the surplus.
   i. Have students numbered 2, 3 and 4 participate while students numbered 1 sit out. The students numbered 1 will represent the elk harvested during hunting season.
   ii. Give students 5 minutes to collect food for the winter.
   iii. Have students tabulate the amount of food they collected.
   iv. Record the number of survivors.
   v. Discussion:
     • How many elk survived? Why?
   vi. This part could be played several times with varying results explained by normal high and low cycles encountered in any wildlife population.
   vii. Remove 1/3 of the tokens to simulate the result of
     1. building a shopping center
     2. building a factory
     3. building highways
     4. removing farmland
     5. building a subdivision
   viii. Have students return the tokens.

i. Round 4—Large population, reduced food supply with habitat change. This simulates an additional 5 years passing. Reproduction among survivors has caused the elk population to increase. Surplus elk were produced. What happens when the habitat changes?
   i. Have all students participate.
   ii. Give students 5 minutes to collect fall food.
   iii. Have students tabulate the amount of food each collected.
   iv. Record the number of survivors.
   v. Discussion:
     • What did the removal of food tokens represent?
     • How many elk survived?
     • What does wildlife need most for survival and where do they find it?

Wrap up

1. In which round did the largest percentage of elk survive? Why?

2. What happened in Round 2 when the elk exceeded the carrying capacity of the environment?

3. Would there be more elk if hunting were stopped?

Assessment

Have students graph the data collected while playing the Missouri Elk Game.

Extensions

1. For Hunter Education opportunities in your area, check the web site: http://mdc.mo.gov/hunt/huntered/.

2. Instruct students to write about their experiences from the elk's point of view. Include how difficult or easy it was to find food and water to survive each round. What happened when the carrying capacity was exceeded? How could an elk's experience be related to human populations throughout the world?

Resources

- MDC video: *Back to the Wild*
- *Hunting and Trapping Regulations* booklet
- *Wildlife Code of Missouri* booklet

3.3 Tally Sheet

Rounds: Carrying Capacity Comparisons	# at Beginning of Round	# at End of Round (Survivors)	Survival Rate (Divide the # of survivors by the # of animals at beginning of Round)
Round 1 Small Population Fixed Food Supply			
Round 2 Large Population Fixed Food Supply			
Round 3 Reduced Population Fixed Food Supply Hunters as Predators			
Round 4 Large Population Reduced Food Supply Habitat Change			

Elk Information Sheet

Elk, *Cervus elaphus*, belong to the deer family. Many attributes of elk are similar to the more familiar white-tailed deer. Like deer, male elk have antlers; females do not. Elk habitat needs are also similar to deer. Like deer, elk need areas to feed, bed and take cover, and they also need a nearby source of water. Food habits are similar with both species being browsers and grazers. Like deer, elk suffered severe population declines in the 1830's due to over exploitation for meat, hide and antlers, but mostly due to habitat changes when settlers turned open grazing lands and forests into homesteads, towns, and agricultural lands. Before settlement times, both species were abundant throughout Missouri.

Here is where the species differ. Conservation efforts were able to bring white-tailed deer populations back in the state, but by 1865, elk were extirpated (completely removed from the area) according to historical accounts. Currently, the Department of Conservation is working towards restoring this native animal to a small, targeted zone in southeastern Missouri. Restoration efforts would bring back a unique and majestic species to a portion of its former range.

Description of Elk

Male elk (bulls) are 600-800 pounds and stand five feet at the shoulder. Antlers, which are shed each year, can weigh up to 40 pounds. Females (cows) can be 400-600 pounds and stand 4½ feet at the shoulder. In summer, the coat is smooth and reddish brown, but in the winter these animals sport a light brown coat with darker hair on the head, neck and legs and a mane from the neck to the chest.

The home range (area travelled and defended) of bulls can be 15,000-20,000 acres. Outside of the mating season, bulls live alone or in bachelor groups. Females form loose herds with cows, calves (young elk) and yearlings. During mating season, called the rut, which occurs in late September-early October, males use high pitched squeals, called bugles, to keep their harems (groups of cows and calves) together and to intimidate other bulls. During this time, bulls may clash antlers to defend their harems. The rut is an awe-inspiring event to see and hear.

Most calves are born from mid-May to early July after an 8½ month gestation. They are about 35 pounds at birth and gain weight rapidly. Elk have only one offspring per year, so they do not have the reproductive potential of deer that often have twins and triplets. Because of this, elk populations will grow much slower than deer.

Due to their large size, elk have few predators other than humans, mountain lions, and wolves. Historically in Missouri, wolves were the primary predator but have been extirpated from the state. While several sightings of mountain lions have been verified in Missouri, they are also considered extirpated since there is no evidence of a breeding population in the state. Coyotes and black bear will take young calves. The elk population in Missouri, when restored, would be managed primarily by hunting.

Food Habits

Elk are herbivores, consuming predominantly herbaceous plants like grasses and forbs (broadleaf plants). They feed by grazing slowly across the landscape. They will also eat browse, or woody vegetation such as tree bark and twigs. When in short supply, food can be a limiting factor (impacting the survival of the animals).

The diet of elk varies by season, location and availability of plant species. In spring, grasses comprise 85 percent of their diet. In summer and fall, grasses, forbs and some woody plants (twigs and leaves) are consumed as grasses become dried and less palatable. In winter, shrubs become more important in the diet.

The average adult elk (over 500 lbs) eats about 15 pounds of food a day in the spring, summer and fall. In the winter, the average amount eaten is 10 pounds, probably due to the dependence on browse, which is more difficult to chew.

Optional Activity 3A
Mark and Recapture: Alternative Method

Estimated time
(1) 50-minute class period

Objectives
Students will be able to:
1. Describe the different ways ecologists measure populations.

2. Describe the ways resource managers sample populations.

3. Explain how scientists use mark-recapture methods to estimate population size.

Teacher Preparation
This activity can be used in a classroom to prepare for *Essential Activity 3.1*.

Have students work in groups of 3 or 4. Provide one sample (bean population) for each group. Use the same number of beans for each group (in which case they should come up with similar population estimates) or use different numbers (which could simulate different years or locations of study). Students will use the Lincoln-Petersen estimate found on page 29 of *Nature Unbound*.

$$N = \frac{n_1 n_2}{m_2}$$

- n1 is the number of individuals marked and released in the first sample
- n2 is the total number of individuals captured in the second sample
- m2 is the number of marked individuals in the second sample

Materials
Student science notebooks
Pencils
Container or paper lunch bag
Approximately 1 pound each of two different kinds of dried beans (similar size; two different colors)

Procedure
1. Distribute a bean population sample (paper bag or container containing a set number of beans of one color) to each student group. Use 100 beans of one color for each group to start. Additional experiments may be conducted using different starting amounts for each group.

2. Have each group "sample the population" by pulling out as many beans as they can in a set period of time (two to five seconds). Students should not look at the beans in the bag, and the beans should be pulled out one at a time. Additional experiments may be conducted using different amounts of time or by grabbing handfuls from the bag.

3. Have students record the number of beans removed within the set time. This number represents n_1.

4. Beans removed from the sample in step #2 should be replaced with a different color bean of similar size.

5. Shake or mix the beans in the container. Have each group "sample the population" again (repeat step 2) without looking at the beans in the bag as they are removed one by one.

6. The number of beans pulled out should be recorded (n_2) and the number of different colored beans should be noted (m_2).

7. Have students estimate their population using the Lincoln-Petersen estimate.

8. Have each student summarize their findings and describe the pros and cons of this method of population estimation in their science notebooks.

Wrap up

1. Discuss student findings and observations.

2. Were there differences in group estimates if each group received the same number of beans to sample? Why?

3. Review the assumptions of this method (p. 29 in *Nature Unbound*).

4. Discuss the pros and cons of this sampling technique.

Assessment

1. Check student science notebooks for accuracy of population estimate.

2. Check student summaries for understanding.

Extension

The experiment may be modified in several ways:
1. Use different numbers of beans to start with for each group (as suggested in procedure #1). Can the groups arrive at a good estimate? Why? Is the estimate better when the initial population is larger or smaller? Why or why not?

2. Use different amounts of time to remove beans (as suggested in procedure #2). How does this affect the accuracy of the population estimate? Is the estimate better when more of the population is captured in the first sample? Why or why not?

3. How would using two different size beans affect the estimate? Which assumption for the estimate does that scenario test?

4. Devise experiments to test the other assumptions of this method.

Lesson 3
End of Chapter Assessment

1. For each limiting factor listed, explain why it can be a limiting factor. Use examples in your explanation.

Limiting Factor	Explanation
Sunlight	
Food availability	
Disease	

2. Key measurements of a population that ecologists make are:
   a. Size, number of predators and carrying capacity
   b. Size, density and carrying capacity
   c. Size, density and dispersion
   d. Size, carrying capacity and dispersion

3. Under what conditions might a population show a clumped pattern?

4. Assumptions of the Lincoln-Petersen method include:
   a. All individuals have the same probability of being caught.
   b. Marking affects survival.
   c. Marked individuals lose their marks between captures.
   d. All of the above

5. Give an example of a testable question that a scientist might ask about a population. Write a hypothesis for this question.

6. How would you determine the population of white oaks in a Missouri forest?

7. Population x is increasing. What factors might cause the increase?

8. How do resource managers predict how a population might change over time?

9. Which graph depicts a population change with abundant resources?
   a. Uniform dispersion
   b. Density-independent
   c. J-shaped curve
   d. Emigration

10. True or False. An ice storm, a drought and a toxin spill are all density-dependent factors. Explain your answer.

11. Is hunting a compensatory or additive mortality? Explain how you determine this.

12. Explain what happens if a population were to exceed the carrying capacity of an area.

13. Explain the difference between biological and cultural carrying capacity.

14. A wetland area manager is preparing for the upcoming waterfowl season. For the past two years, waterfowl censuses indicate that populations are declining. How would this information influence the manager's decisions regarding waterfowl hunting?

Lesson 3
End of Chapter Assessment Scoring Guide

1. For each limiting factor listed, explain why it can be a limiting factor. Use examples in your explanation.
   Answer:

Limiting Factor	Explanation
Sunlight	**Without enough light, green plant growth can be slowed, and plant populations that require a lot of sun will diminish.**
Food availability	**Without enough food, animal populations (like bobcat) will suffer because many die of starvation.**
Disease	**An outbreak of disease can kill animals (like chronic wasting disease in deer), and the population will decline.**

(3 points)

2. Key measurements of a population that ecologists make are:
   a. Size, number of predators, and carrying capacity
   b. Size, density, and carrying capacity
   c. Size, density and dispersion
   d. Size, carrying capacity and dispersion
   Answer: c **(1 point)**

3. Under what conditions might a population show a clumped pattern?
   Answer: Answers will vary but could include patchiness of habitat, nest sites, sunlight, food or grouping for mating or winter survival. **(1 point)**

4. Assumptions of the Lincoln-Petersen method include:
   a. All individuals have the same probability of being caught.
   b. Marking affects survival.
   c. Marked individuals lose their marks between captures.
   d. All of the above
   Answer: a **(1 point)**

5. Give an example of a testable question that a scientist might ask about a population. Write a hypothesis for this question.
   Answers will vary. For example, if the question was "How many monarch butterflies are in our schoolyard?" The hypothesis could be "I think there could be 100 because we have a lot of flowering plants." **(2 points)**

6. How would you determine the population of white oaks in a Missouri forest?
   Answer: You could walk a small patch of forest and count every tree (census). For a larger space, you could take a sample—either a quadrat or transect and multiply by the number of samples contained in the area. **(2 points)**

7. Population x is increasing. What factors might cause the increase?
   Answer: Births or immigration could cause a population increase. **(2 points)**

8. How do resource managers predict how a population might change over time?
   Answer: The population size in one year is the current population size multiplied by the per capita growth rate. If we want to estimate the population size at three years, we could perform the calculation three times. Since birth and death rates vary with ages of individuals in the population, per capital growth rate can be determined for each age class (called a life table) to provide a more accurate estimate. **(2 points)**

9. Which graph depicts a population change with abundant resources?
   a. Uniform dispersion
   b. Density-independent
   c. J-shaped curve
   d. Emigration
   Answer: c **(1 point)**

10. True or False. An ice storm, a drought and a toxin spill are all density-dependent factors. Explain your answer.
    Answer: False. These are density independent factors. **(2 points)**

11. Is hunting a compensatory or additive mortality? Explain how you determine this.
    Answer: Hunting could be either compensatory or additive. For most species, hunting seems to be compensatory up to a point. You determine this by knowledge of population numbers. If populations do not rebound, hunting is additive; if populations can be sustained without long term declines, hunting is compensatory. **(4 points)**

12. Explain what happens if a population were to exceed the carrying capacity of an area.
    Answer: When a population grows larger than carrying capacity, there aren't enough resources, and deaths outnumber births, bringing the population size back to carrying capacity. **(2 points)**

13. Explain the difference between biological and cultural carrying capacity.
    Answer: Biological carrying capacity is the number of individuals of a species that the habitat will support. Cultural carrying capacity is the number of individuals that people will tolerate. The difference is in perspective—habitat or people. **(1 point)**

14. A wetland area manager is preparing for the upcoming waterfowl season. For the past two years, waterfowl censuses indicate that populations are declining. How would this information influence the manager's decisions regarding waterfowl hunting?
    Answer: Answers should indicate that the manager would be looking at changing bag limits, harvest season and harvest methods. **(1 point)**

Lesson 4: Interactions—Costs and Benefits of Survival

Estimated time
(3) 50-minute class periods

Science CLEs

EC.1.A.a. Explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (i.e., mutualism, commensalism, parasitism)

EC.1.A.b. Explain how cooperative (e.g., symbiotic) and competitive (e.g., predator/prey) relationships help maintain balance within an ecosystem

EC.1.A.c. Explain why no two species can occupy the same niche in a community
(The functional role of a species is not limited to its placement along a food pyramid; it also includes the interactions of a species with other organisms while obtaining food. For example, the methods used to tolerate the physical factors of its environment, such as climate, water, nutrients, soils, and parasites, are all part of its functional role. In other words, the ecological niche of an organism is its natural history: <u>all the interactions and interrelationships of the species with other organisms and the environment</u>)

EC.3.C.a. Identify examples of adaptations that may have resulted from variations favored by natural selection (~~e.g., long-necked giraffes, long-eared jack rabbits~~) and describe how that variation may have provided populations an advantage for survival

IN.1.A.a. Formulate testable questions and hypotheses

IN.1.B.a. Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., ~~microscopes~~, thermometers, analog and digital meters, computers, ~~spring scales~~, ~~balances~~, metric rulers, ~~graduated cylinders~~)

IN.1.B.e. Calculate the range, average/mean, percent, and ratios for sets of data

IN.1.B.f. Recognize observation is biased by the experiences and knowledge of the observer (e.g., strong beliefs about what should happen in particular circumstances can prevent the detection of other results)

IN.1.C.a. Use quantitative and qualitative data as support for reasonable explanations (conclusions)

IN.1.C.b. Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable)

Vocabulary

Interaction
Competition
Exploitation
Mutualism
Indirect competition
Intraspecific competition
Interspecific competition
Timber stand improvement
Stand
Niche
Fundamental niche
Realized niche
Competitive exclusion principle
Resource partitioning

Predators
Herbivores
Parasites
Host
Brood parasites
Warning coloration
Mimic
Model
Batesian mimicry
Mullerian mimicry
Commensalism
Symbiosis
Predator-prey cycles

Objectives

1. Explain how competition affects the growth, survival and reproduction of organisms.

2. Define niche and describe various aspects that make up a species' niche.

3. Distinguish between a species' fundamental and realized niche.

4. Explain the competitive exclusion principle (Gause's Law).

5. Describe various kinds of exploitation and explain how each affects the organisms involved.

6. Describe adaptations that help organisms exploit other organisms or avoid being exploited.

7. Explain commensalism and its effects on the organisms involved.

8. Explain mutualism and its effects on the organisms involved.

9. Explain and give examples of how interactions maintain balance within an ecosystem.

Resource Management Objectives

1. Explain how timber stand improvement reduces competition among trees.

2. Explain how resource managers optimize the number of niches in a wetland by manipulating water flow.

3. Describe strategies resource managers could take to thwart cowbird brood parasitism.

Essential Questions

1. Why can't two species have the exact same requirements and same role in a community?

2. How do relationships between organisms maintain balance in an ecosystem?

Teacher Notes

Students should read *Nature Unbound* Chapter 4 before beginning Lesson 4 activities.

Availability and use of digital cameras and/or video cameras would greatly enhance *Activity 4.1*. However, students could create sketches and written reports from their observations if cameras are not available.

Outline of Answers to Objectives

See following page.

Essential Activities

Essential Activity 4.1—On the Hunt for Interactions
Essential Activity 4.2—Tree Inventory

End of Chapter Assessment

Lesson 4 Questions and Answer Key

Summary

- Organisms compete for limited resources.
- Competition affects the growth, survival and reproduction of the organisms involved.
- A species' niche describes its way of life and role in an ecosystem.
- Two species cannot have the same niche in an ecosystem.
- Exploitation benefits one organism but harms another.
- Organisms have adaptations to help them exploit other organisms or avoid being exploited.
- Commensalism benefits one organism but does not affect another.
- Mutualism benefits each organism that participates in the interaction.
- Interactions maintain balance within an ecosystem.

Outline of Answers to Objectives

1. **Explain how competition affects the growth, survival and reproduction of organisms.** (p. 43)
   a. When a greater number of organisms competes for the same amount of resources, the growth of each organism is diminished.
   b. When resources are scarce, competition for food or space can affect survival. Organisms may not get enough to eat and die. More time may be spent searching for limited resources in marginal habitats causing greater vulnerability to weather or predators.
   c. When resources are scarce, competition may cause a female to go hungry, reducing survival and reproductive ability.

2. **Define niche and describe various aspects that make up a species' niche.** (p. 45)
   a. A niche describes everything affecting a particular species' existence—its way of life and role in an ecosystem.
   b. A species' niche includes the range of environmental conditions the species can tolerate, what it needs to grow, survive, and reproduce, and how it interacts with its biotic and abiotic environment.

3. **Distinguish between a species' fundamental and realized niche.** (p. 45)
   a. A fundamental niche includes the environmental conditions the species can tolerate and the resources it is capable of using under ideal conditions.
   b. The realized niche is the portion of the fundamental niche a species uses in the presence of other species. Competition and predation may cause a species to use only part of the resources that make up its fundamental niche.

4. **Explain the competitive exclusion principle (Gause's Law).** (p. 47)
   a. The competitive exclusion principle states that two species with identical niches cannot coexist over time.
   b. When two species compete for exactly the same resources, one will be more efficient than the other at gathering those resources.
   c. The more efficient species will fill the niche with more of its offspring, eventually leaving no resources for the less efficient species which will die off in time.

5. **Describe various kinds of exploitation and explain how each affects the organisms involved.** (p. 48; p. 54)
   a. Three forms of exploitation are predation, herbivory and parasitism.
   b. Exploitation benefits one organism but harms another.
   c. Predation involves one organism, the predator, gaining energy by catching, killing and eating another organism, the prey.
   d. Herbivory involves one organism, the herbivore, gaining energy by eating plant parts.
   e. Parasitism involves one organism, the parasite, gaining energy by feeding on blood, fluids or tissues of another organism, the host.

6. **Describe adaptations that help organisms exploit other organisms or avoid being exploited.** (p. 48; pp. 50-52)
   a. Keen senses may help a predator find prey.
   b. Predators may have adaptations such as claws or venom to help catch and consume prey; behavioral adaptations such as ambush techniques also help some predators catch prey.
   c. Prey species may avoid detection or evade capture by use of blending coloration, warning coloration, Batesian mimicry or Mullerian mimicry.
   d. Many prey species use speed to avoid capture; slower prey species have shells or bony plates to protect them from attack.
   e. Herds, flocks and schools protect some prey species by having more eyes to detect danger.
   f. Some prey species use confusion or scare tactics to avoid predation; some use toxic chemicals to discourage predators.
   g. Some plants use structures such as thorns or spikes to defend against herbivores; other plants may employ chemicals.
   h. Herbivores may use grinding teeth to chew tough plant tissues or microorganisms to digest cellulose.
   i. Many parasites have keen senses, sucking mouthparts or hooklike appendages and /or elaborate life cycles to help them find, feed on and disperse from their hosts.

7. **Explain commensalism and its effects on the organisms involved.** (pp. 52-53)
   a. Commensalism is an interaction of two organisms where one organism benefits but the other is not affected.
   b. Some ecologists argue that the interaction is commensalism only when the benefiting organism cannot survive without the other species.
   c. Others argue that the relationship has to be slightly beneficial or harmful to the organism originally thought to be unaffected; thus they believe pure commensalism does not exist.

8. **Explain mutualism and its effects on the organisms involved.** (pp. 53-54)
   a. **Mutualism** is an interaction of two organisms where both benefit.
   b. Both can benefit from food and energy efficiency.
   c. Mutualism can help one of the organisms reproduce.
   d. The relationship can increase the safety of participants.
   e. When one organism could not survive without the other, the relationship is termed symbiosis.
   f. Mutualism, parasitism and some kinds of commensalism are all types of symbiosis.

9. **Explain and give examples of how interactions maintain balance within an ecosystem.** (pp. 54-55)
   a. Loss of mutualistic relationships would ripple through the biosphere until very few organisms remained; thus these relationships are important to the survival of both species involved.
   b. When prey species disappear, predators soon decline; thus predators keep prey populations in check and maintain balance in the ecosystem.

Resource Management Objectives

1. **Explain how timber stand improvement reduces competition among trees.** (p. 44)
   By removing some trees (unwanted or low value trees), the remaining trees do not have to compete for sunlight or water which allows those trees to grow faster. With less energy needed for competition, trees that remain can devote more energy to survive disease and pest infestations and for reproduction.

2. **Explain how resource managers optimize the number of niches in a wetland by manipulating water flow.** (p. 46)
   Resource managers manipulate how deep, how long and when wetland pools flood. Often, managers begin flooding those pools in late summer creating mudflats for migrating shorebirds. By fall, the water is a little deeper and covers more of the pool attracting large flocks of ducks. In early spring, flooded vegetation begins to decompose attracting insects and providing food for waterfowl. In late spring, managers begin slowly drawing water off wetland pools, dispersing seeds of wetland plants and creating mudflats for shorebirds and breeding pools for amphibians. Sometimes managers leave pools flooded throughout the summer as spawning grounds and nurseries for fish. Wetlands dry up later in the summer creating small pools of concentrated fish for herons to hunt. Thus, through manipulation of water flow, managers meet the niche requirements of a vast array of species throughout the year.

3. **Describe strategies resource managers could take to thwart cowbird brood parasitism.** (p. 49)
   Managers (with the proper federal permits) might trap and kill adult cowbirds and remove cowbird eggs from host nests. This is usually not cost effective or successful on a large scale. For large tracts, keeping those forests from being divided into smaller tracts is the best way to reduce cowbird parasitism.

Essential Activity 4.1
On the Hunt for Interactions

Estimated time
(1) 50-minute class period (for observation activity)
(1) 50-minute class period (for presentations)

Objectives
Students will be able to:

1. Explain how competition affects the growth, survival and reproduction of organisms.

2. Explain the competitive exclusion principle (Gause's Law).

3. Describe various kinds of exploitations and explain how each affects the organisms involved.

4. Explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (mutualism, commensalism, parasitism).

5. Describe adaptations that help organisms exploit other organisms or avoid being exploited.

6. Explain and give examples of how interactions maintain balance within an ecosystem.

Teacher Preparation
The schoolyard ecosystem will be used in this activity. Students will search for and record examples of organism interactions. Prompt students to make a strong effort to seek out and find examples of interactions between and among organisms. Students will also describe the adaptations that help an organism exploit other organisms or protect it from being exploited. Students should videotape and/or take pictures of these interactions to include in a short film or PowerPoint presentation to the class. All observations should be recorded in student science notebooks, and students should prepare prompts in their science notebooks that will help them remember the interactions they observe. If the *4.1 Interaction Sheet* is used instead, provide a copy to every student. Have students work in small groups for this activity, but instruct everyone to record observations.

If digital cameras and/or video cameras are not available, have students do this activity by writing descriptions and/or creating sketches.

Materials
Student science notebooks
Pencils
Air thermometers
Copies of *4.1 Interaction Sheet* (one per student; *optional*)
Digital camera and/or video recorder (*optional*)

Procedure
1. Have students complete their science notebook headings and record questions they have during the activity.

2. Have students create prompts in their science notebook based on their readings from Chapter 4 of *Nature Unbound* or hand out the *4.1 Interaction Sheet* and allow time for students to add notes to the sheet from their student book.

3. In the schoolyard ecosystem:
   a. Explain the boundaries and time limit.
   b. Instruct students to:
      i. Find examples of organism interactions in the schoolyard ecosystem.
      ii. Take pictures and/or videos of the interactions they observe.
      iii. Write detailed descriptions of their observations to support their pictures and/or videos.
      iv. Sketch the observed interactions if cameras are not available.
      v. Develop and record in their science notebooks two questions about the interactions observed.
      vi. Summarize their observations.

4. Have students create a PowerPoint or video that explains one or two of the organism interactions observed. This can be done as homework.

5. Students may be assigned two specific interactions to present or choose two from their observations.

6. Presentations must include:
   a. Pictures, sketches and/or videos of observed organism interactions.
   b. Explanation of at least two observed interactions.
   c. Ways the observed interactions might affect the growth, survival and/or reproduction of the organism.
   d. A brief discussion of whether Gause's Law could be applied to their observed interactions.
   e. Examples of as many of the following interactions as possible:
      i. Predator/prey
      ii. Mutualism
      iii. Commensalism
      iv. Parasitism
      v. Indirect competition
      vi. Intraspecific competition
      vii. Interspecific competition

Wrap up

1. Discuss student findings and observations.

2. List student questions.

3. Discuss which of these can be made into testable questions.

4. How could an experiment, further observation or a field study be created from these questions?

5. Have students choose two observed species.
   a. Did they occupy the same niche?
   b. What might happen if they did?

6. Why is Gause's Law (competitive exclusion principle) considered a key idea of ecology?

Assessment

See *Appendix 3: Scoring Guide for Oral Presentation* on page 215.

Extensions

1. If there are cowbirds in the schoolyard ecosystem, have students observe cowbird behaviors.

2. How do cowbird behaviors affect other bird species?

4.1 Interaction Sheet

Directions: Find examples of organism interactions in the schoolyard ecosystem and record them in the appropriate boxes.

Interaction	Species involved in the interaction	Observation/proof of this interaction	Adaptation observed that helps one organism exploit the other organism	Adaptation observed that helps one organism avoid being exploited
Predatory/prey				
Parasitism				

Interaction	Species involved in the interaction	Observation/proof of the interaction	Adaptation observed that helps the organism
Mutualism			
Commensalism			

Interaction	Species involved in the interaction	Observation/proof of the interaction
Intraspecific competition		
Interspecific competition		

Essential Activity 4.2
Tree Inventory

Estimated time
(1) 50-minute class period

Objectives
Students will be able to:
1. Explain how competition affects the growth, survival and reproduction of organisms.

2. Explain how timber stand improvement reduces competition among trees.

3. Describe the ways resource managers sample populations.

Teacher Preparation
Before foresters decide how to manage a forest, they need to know what is growing there. The process of gathering this information is called an inventory or timber cruise. During the inventory, the forester measures the diameter and height of the trees, records the kinds of trees, looks for signs of insects and disease problems and notes the types of wildlife habitat found.

The information foresters gather about the forest helps them make decisions about care needed. By knowing the diameter and height of a tree, they can find its board foot volume. A board foot is the standard measure of lumber and is defined as a piece of wood 12 inches square and 1 inch thick. Knowing the board foot volume of a forest helps determine the need for a harvest.

The diameter of a tree, rather than the circumference, is measured for board foot calculations. The diameter of a tree is always measured 4.5 feet above the ground. This is called diameter at breast height (DBH). A forester's tool, called a Biltmore stick, is commonly used to measure DBH. At first glance, it looks like a yardstick but the increments decrease in size as the tree diameter increases. The Biltmore stick is based upon the geometric principle of similar triangles. A hypsometer is used to measure the height of trees. The hypsometer is also based upon geometry. Usually, the Biltmore and hypsometer are placed on the same stick for easy use.

Have students work in small groups to learn methods used by foresters to conduct tree inventories. Have students review Ecology in Action, "Timber Stand Improvement," on page 44 of *Nature Unbound*. Ideally, students would sample a large wooded area; however, an area with trees >2 inches in diameter will suffice.

Review with students the use of Biltmore (scale) sticks and the procedure for determining height of a tree.
Note: These measurements will be in customary units because this is forestry measurement standards.

Materials
Student science notebooks
Nature Unbound student book
Pencils
Air thermometer
Tree field guides and/or tree identification guides
Biltmore (scale) sticks or measuring tape
Flagging tape to mark trees
Copies of *4.2 Tree Sampling Procedures* sheet (one per group)
Copies of *4.2 Data Sheet A—Tree Observations* (one per student; *optional*)
Copies of *4.2 Data Sheet B—Plot Summary* (one per student; *optional*)

Procedure

1. Establish a plot using the *4.2 Tree Sampling Procedures Sheet* or select 20 trees within the schoolyard ecosystem.

2. Have students complete their science notebook headings.

3. When students have determined their plot (or trees) have them begin taking and recording data starting with tree #1. They can use the data sheet provided or create their own data table. Data for each tree should include:
   a. tree species
   b. DBH (diameter at breast height) in inches
   c. tree height (in feet)
   d. Other observations, including but not limited to:
      i. presence of snags (large dead limbs)
      ii. general health of tree

4. Have groups compare and summarize their data for the plot including:
   a. most common species
   b. dominant species
   c. averageDBH
   d. maximumDBH
   e. maximum height
   f. number of snags
   g. general health of trees

Wrap up

1. How can the number of trees in the schoolyard ecosystem be determined?

2. How many trees are in the schoolyard ecosystem?

3. What is the dominant tree species?

4. What was the largest tree?

5. How healthy were the sampled trees?

6. List the items students were curious about.

7. Discuss which of these items can be made into testable questions.

8. How could an experiment, observations or a field study be created from these questions?

Assessment

Check data sheets for completion and accuracy.

Extensions

1. If students have access to a forested area, have them determine the basal area and stand density (see MDC publication *Forest Management for Missouri Landowners*, pp. 94-96).

2. Have students create an experiment or field study from one of the testable questions.

3. Have students join Forestkeepers. Teachers can join Forestkeepers at no cost and have their students monitor the tree health in their schoolyard ecosystems. Student observation forms are available, and the recorded information becomes part of a database reflecting the condition of our trees and forests. For more information on Missouri Forestkeepers or to join, go to http://forestkeepers.org.
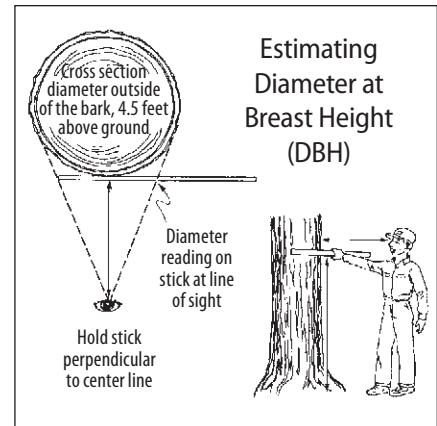
4.2 Tree Sampling Procedures Sheet

Establish a Plot:

1. Locate an area with at least 20 trees that are at least 2 inches in diameter, measured 4.5 feet from the ground.

2. Record tree data for 20 trees, using flagging tape to mark trees already measured.

DBH (diameter at breast height) in inches (DBH may be measured using a Biltmore stick or a tape measure):

Using a Biltmore stick:

1. Hold the stick horizontally against the trunk of the tree, 4.5 feet from the ground and 18 inches from your eyes.

2. Look directly at the center of the tree. Without moving your head, shift your eyes to the left and line up the zero end of the stick with the outside edge of the tree.

3. Without turning your head, look at the right side of the tree and read the number closest to where your line of sight crosses the stick. This is the tree's diameter in inches.

4. If the trunk does not have a uniform diameter, measure the diameter at both the widest and narrowest points and average the two.


Estimating Diameter at Breast Height (DBH)

Cross section diameter outside of the bark, 4.5 feet above ground

Diameter reading on stick at line of sight

Hold stick perpendicular to center line

Using a tape measure:

1. Measure 4.5 feet up from the ground on the tree.

2. Wrap the measuring tape around the tree at this height. This is the circumference.

3. Divide the circumference by 3.14 to obtain the diameter.

Tree height (in feet)

1. Pace off 50 feet from the tree, as level as possible with its base.

2. Find the top of the tree.

3. Hold the hypsometer side of the stick 18 inches from your eye in a vertical position.

4. Line up the zero end with the base of the trunk.

Estimating Tree Height

Height in feet

Line of sight

Held 18" from eye

Base of tree

50 ft.

5. Without moving your head, shift your eyes to the treetop. Be sure the stick is vertical and not tilted. The point where your line of sight intersects the stick is the height of the tree in feet.
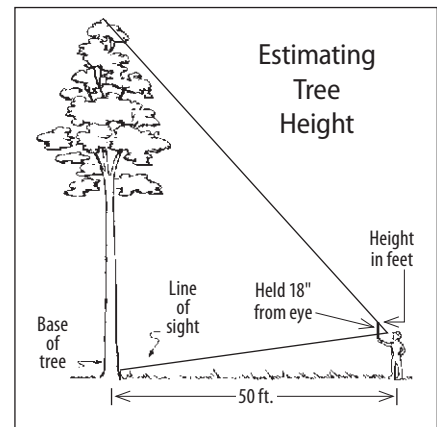
Tree Health

1. Look at the crown. Is it leafy throughout? If not, what percent of the crown is covered with foliage?

2. Look at the limbs and trunk. Do they appear healthy? Are limbs dead or dying? Is there visible evidence of disease? What percent is healthy?

3. Look at the leaves. Do they appear healthy or are they yellowing, damaged or diseased? If so, what percent is healthy?

4.2 Data Sheet A—Tree Observations

Directions: Complete the data sheet for 20 trees. For each tree, identify the species. Using the Biltmore stick or measuring tape, determine the diameter at breast height (DBH) in inches. Determine the height, in feet. Count the number of snags (large dead limbs) on the tree. Look at the crown, leaves and trunk to determine the general health. See *Tree Sampling Procedures Sheet* for more specific directions.

Location _____   Weather _____

Plot# _____   Date _____

	Species	DBH	Height	# Snags	Health comments
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

4.2 Data Sheet B—Plot Summary

Directions: Complete *4.2 Data Sheet B* using information gathered from your plot and recorded on *4.2 Data Sheet A*.

Location _____   Weather _____

Plot# _____   Date _____

Most common species (greatest number from the species list) _____

Dominant species (tree species making up most of canopy) _____

Average DBH (in inches) _____   Maximum DBH (in inches) _____

Maximum height (in feet) _____   Number of _____

Comments on general health of trees in the sample _____

_____

_____

_____

_____

Summary/Conclusions of plot information

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Lesson 4
End of Chapter Assessment

1. Fill in the missing items on the chart below.

Type of Interaction	Example	Outcome
	Cattle and cowbirds	
	Elk and grass	
	Lichens	
	Flowering Plants	

2. Why are the three interactions in #1 above important?

3. Define competition and give one example.

4. How does competition affect the growth, survival and reproduction of the organisms involved?

5. What would happen over time if two species occupied the exact same niche?

6. Which is an example of an adaptation that helps organisms exploit other organisms?
   a. glossy leaves of some plants
   b. spines on a cactus
   c. long, silky fur
   d. keen eyesight

7. Give two examples of adaptations and explain how they help organisms avoid exploitation.

8. The competitive exclusion principle is called:
    a. Boyle's Law
    b. Gause's Law
    c. Darwin's Law
    d. None of the above

9. Timber stand improvement reduces competition by:
    a. removing unwanted trees
    b. reducing understory trees
    c. removing the largest trees
    d. all of the above

10. The most effective way to reduce cowbird parasitism is to:
    a. remove cowbird eggs from host nests
    b. kill cowbirds
    c. keep large tracts of forests intact
    d. divide forests into smaller tracts

11. Define niche. How do wetland managers manipulate wetlands to provide niche requirements for an array of species?

12. Formulate a testable question and hypothesis concerning intraspecific or interspecific competition. (For instance, an example in the text was of plants in pots. **Question:** Which pot's flowers will grow taller: the pot with fewer plants or the pot with more plants? **Hypothesis:** The pot with fewer plants will grow taller plants.)

13. A landowner has 40 acres of forest land that is predominantly oak-hickory. Years of little or no management have left the area with an aging canopy of desirable species like oak and a less desirable understory with maple and ash. Oak seedlings require sunlight to successfully grow to canopy-sized trees and will not thrive in shade. There are few oak seedlings on the forest floor. As a resource forester, how would you manage the area to guarantee oaks survive and grow to replace the aging canopy?

Lesson 4
End of Chapter Assessment Scoring Guide

1. Fill in the missing items on the chart below.
   Answer: (3 points)

Type of Interaction	Example	Outcome
Commensalism	Cattle and cowbirds	**Cowbirds benefit from following cattle to eat insects on and stirred up by cattle, but cattle are mostly unaffected from the interaction.**
Exploitation	Elk and grass	**Elk benefit from eating grass, but the grass is negatively impacted.**
Mutualism	Lichens	**Lichen are two organisms, a fungus and algae; both species benefit.**
	Flowering plants	**Pollinators such as hummingbirds, honeybees and butterflies would die without flowering plants. Without pollinators, flowering plants would suffer.**

2. Why are the three interactions in #1 above important?
   Answer: All three provide a benefit to at least one of the organisms. Mutualism maintains the most obvious balance in the ecosystem. Mutualism is important to the survival of both species involved. For example, when prey species disappear, predators soon decline. By keeping prey populations in check, predators help maintain balance in an ecosystem. **(1 point)**

3. Define competition and give one example.
   Answer: Competition is an interaction that occurs when neither organism benefits from the interaction. This is the most common interaction in nature. Examples will vary but could include birds at your feeder, trees in a forest, organisms on a rotten log. **(2 points)**

4. How does competition affect the growth, survival and reproduction of the organisms involved?
   Answer: When a greater number of organisms compete for the same amount of resources, the growth of each organism is diminished. When resources are scarce, competition for food or space can affect survival. Organisms may not get enough to eat and die. More time may be spent searching for limited resources in marginal habitats causing greater vulnerability to weather or predators. When resources are scarce, competition may cause a female to go hungry, reducing survival and reproductive ability. **(2 points)**

5. What would happen over time if two species occupied the exact same niche?
   Answer: The competitive exclusion principle states that two species with identical niches cannot coexist over time. When two species compete for exactly the same resources, one will be more efficient than the other at gathering those resources. More efficient species will fill the niche with more of its offspring eventually leaving no resources for the less efficient species which will die off in time. **(2 points)**

6. Which is an example of an adaptation that helps organisms exploit other organisms?
   a. glossy leaves of some plants
   b. spines on a cactus
   c. long, silky fur
   d. keen eyesight
   Answer: d **(1 point)**

7. Give two examples of adaptations and explain how they help organisms avoid exploitation.
    Answers may vary: Prey species may avoid detection or evade capture by use of blending coloration, warning coloration, Batesian mimicry or Mullerian mimicry. Many prey species use speed to avoid capture; slower prey species have shells or bony plates to protect them from attack. Living in herds, flocks or schools protects some prey species by having more eyes to detect danger. Some prey species use confusion or scare tactics to avoid predation; some use toxic chemicals to discourage predators. Some plants use structures such as thorns or spikes to defend against herbivores; other plants may employ chemicals. **(2 points)**

8. The competitive exclusion principle is called:
    a. Boyle's Law
    b. Gause's Law
    c. Darwin's Law
    d. None of the above.
    Answer: b **(1 point)**

9. Timber stand improvement reduces competition by:
    a. removing unwanted trees
    b. reducing understory trees
    c. removing the largest trees
    d. all of the above
    Answer: a **(1 point)**

10. The most effective way to reduce cowbird parasitism is to:
    a. remove cowbird eggs from host nests
    b. kill cowbirds
    c. keep large tracts of forests intact
    d. divide forests into smaller tracts
    Answer: c **(1 point)**

11. Define niche. How do wetland managers manipulate wetlands to provide niche requirements for an array of species?
    Answer: Niche is the range of environmental conditions that a species can tolerate, what the species needs to grow, survive and reproduce, and how the species interacts with its biotic and abiotic environment. Resource managers manipulate how deep, how long and when wetland pools flood. Through manipulation of water flow, niche requirements of a vast array of species are met throughout the year. **(3 points)**

12. Formulate a testable question and hypothesis concerning intraspecific or interspecific competition. (For instance, an example in the text was of plants in pots. **Question:** Which pot's flowers will grow taller: the pot with fewer plants or the pot with more plants? **Hypothesis:** The pot with fewer plants will grow taller plants.)
    Answers will vary. (2 points)

13. A landowner has 40 acres of forest land that is predominantly oak-hickory. Years of little or no management have left the area with an aging overstory of desirable species like oak and a less desirable understory with maple and ash. Oak seedlings require sunlight to successfully grow to canopy-sized trees and will not thrive in shade. There are few oak seedlings on the forest floor. As a resource forester, how would you manage the area to guarantee oaks survive and grow to replace the aging overstory?
    Answer: The forester would take the following steps:
    1. Remove the current understory of undesirable species with TSI.
    2. Selectively cut the overstory to create openings of sunlight for oak seedlings to grow.
    3. Sow acorns or plant seedlings if natural regeneration of oaks will not occur. In this way, the oaks (sun loving species) would be favored and regenerate to create a new oak forest. **(4 points)**

Lesson 5: Extinction: Causes and Consequences

Estimated time
(4) 50-minute class periods for the activities

Science CLEs

EC.1.A.a Explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (i.e., mutualism, commensalism, parasitism)

EC.1.C.a. Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible adverse effects of human interactions with that ecosystem (e.g., destruction caused by direct harvesting, pollution, atmospheric changes)

EC.1.C.b. Predict and explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents)

EC.1.D.a. Predict the impact (beneficial or harmful) a natural or human caused environmental event (e.g., forest fire, flood, ~~volcanic eruption, avalanche~~, acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on the diversity of different species in an ecosystem

EC.1.D.b. Describe possible causes of extinction of a population

EC.3.C.d. Given a scenario describing an environmental change on a community, hypothesize why a given species was unable to survive

IN.1.A.a. Formulate testable questions and hypotheses

IN.1.A.b. Analyzing an experiment, identify the components (i.e., independent variable, dependent variables, control of constants, multiple trials) and explain their importance to the design of a valid experiment

IN.1.A.c. Design and conduct a valid experiment

IN.1.A.d. Recognize it is not always possible, for practical or ethical reasons, to control some conditions (e.g., when sampling or testing humans, when observing animal behaviors in nature)

IN.1.B.c. Determine the appropriate tools and techniques to collect, analyze, and interpret data

IN.1.C.a. Use quantitative and qualitative data as support for reasonable explanations (conclusions)

IN.1.C.b. Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable)

IN.1.D.a. Communicate the procedures and results of investigations and explanations through oral presentations, drawings and maps, data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities), graphs (bar, single, and multiple line), equations and writings

Vocabulary

Extinction

Extirpation

Natural (background) extinction

Mass extinction

Endangered

Fragmentation

Exotic

Non-native

Introduced

Invasive

Population sinks

Generalists

Specialists

Inbreeding

Allee effect

Objectives

1. Differentiate between extinct, extirpated and endangered.

2. Compare and contrast the causes of previous mass extinctions with those of modern-day.

3. Identify human activities that threaten species with extinction.

4. Describe traits that increase a species' risk of extinction.

5. Explain how the extinction of a species affects other species, including humans.

6. Given a scenario describing an environmental change, predict the effect on the biological community.

Resource Management Objectives

1. Explain why grassland bird populations are declining at an alarming rate.

2. Explain what resource managers are doing to increase grassland bird populations.

3. Describe the threat posed by invasive species.

4. Explain the strategies resource managers use to slow the spread of invasive species.

Essential Questions

1. Why do species become extinct?

Teacher Notes

Students should read *Nature Unbound* Chapter 5 before beginning Lesson 5 activities.

The essential activities for this lesson require approximately two to three class periods each. If research is done as homework, activities will only require two class periods each.

Outline of Answers to Objectives

See page 140.

Essential Activities

Essential Activity 5.1—What Would (Should) You Do?
Essential Activity 5.2—Risks of Extinction

Optional Activities

Optional Activity 5A—Invasive Invasions
Optional Activity 5B—Species of Conservation Concern

End of Chapter Assessment

Lesson 5 Questions and Answer Key

Summary

- Extinction is part of nature.
- There have been at least five mass extinctions in the past, and humans are likely causing a sixth.
- Extinctions occur when species fail to adapt to changing ecological conditions.
- Some species are more prone to extinction than others.
- Extinction has consequences.

Outline of Answers to Objectives

1. **Differentiate between extinct, extirpated and endangered.** (*Nature Unbound* pp. 57, 58 & 60)
   a. Extinction is the complete elimination of an entire species.
   b. Extirpation is when a species disappears from one location but survives in another.
   c. Endangered is when a species is at risk of going extinct in the near future.

2. **Compare and contrast the causes of previous mass extinctions with those of modern-day.** (pp. 59-61)
   a. Likely causes of previous mass extinctions include the following abiotic forces: falling sea levels, climate change, asteroid collisions, shifting continents or volcanic eruptions.
   b. Extinctions of today are more likely a result of biotic forces—specifically, human actions.

3. **Identify human activities that threaten species with extinction.** (pp. 60-61)
   a. Destruction of habitat and fragmentation
   b. Introduction of non-native species
   c. Over-harvesting a population
   d. Burning fossil fuels contributes to climate change

4. **Describe traits that increase a species' risk of extinction.** (p. 65)
   a. Specialized niche
   b. Small population size
      i. Inbreeding
      ii. Allee effect
   c. Restricted geographic range

5. **Explain how the extinction of a species affects other species, including humans.** (p. 66)
   a. Saving species from extinction is a moral issue for many people.
   b. Species provide economic benefits.
   c. Species provide recreational opportunities.
   d. Species maintain balance within the community.

6. **Given a scenario describing an environmental change, predict the effect on the biological community.** (p. 67)
   a. If a keystone predator is extirpated, prey populations can skyrocket which will affect other organisms within the community.
   b. When one species is extirpated and other species have similar niches and roles, there may be little effect on the community.
   c. However, if too many species become extinct or extirpated, other species that rely on them may also disappear.

Resource Management Objectives

1. **Explain why grassland bird populations are declining at an alarming rate.** (p. 64)
   a. There are declines due to
      i. loss of North American grassland habitat and grassland plant diversity
      ii. increased use of herbicide and pesticide
      iii. feral animals
      iv. loss of wintering habitat in Central and South America

2. **Explain what resource managers are doing to increase grassland bird populations.** (p. 64)
   a. Resource managers are increasing grassland bird populations by
      i. restoring native prairies
      ii. encouraging farmers to leave weedy borders around the edges of fields
      iii. encouraging farmers to convert pastures to native grasses
      iv. creating natural disturbances by mowing, disking and setting prescribed fires

3. **Describe the threat posed by invasive species.** (p. 62)
   a. Threats posed by invasive species include
      i. Non-native invasive species grow quickly, reproduce often and bear many offspring.
      ii. Limiting factors may not be present to control their populations.
      iii. Native species are often displaced or go extinct, disrupting the existing ecosystem.
      iv. They can damage agricultural crops and spread disease to native and domesticated plants and animals.

4. **Explain the strategies resource managers use to slow the spread of invasive species.** (pp. 62-63)
   a. Resource managers are working to slow the spread of invasives by
      i. eradicating non-native vegetation by using a combination of burning, mowing and herbicide
      ii. surveying areas to detect outbreaks of invasive species such as emerald ash borer and setting up quarantines for infested areas
      iii. encouraging boaters to use hot water to wash boats, motors and trailers and to let them dry in the sun for five days to kill attached zebra mussels

Essential Activity 5.1
What Would (Should) You Do?

Estimated time
(1) 50-minute class

Objectives
Students will be able to:
1. Identify human activities that threaten species with extinction.

2. Explain how environmental factors (habitat loss, climate change, pollution, introduction of invasive species) can be agents of natural selection.

3. Given a scenario describing a natural environmental change or human activity that adversely affects an ecosystem, describe its impact on biodiversity and hypothesize why a given species may or may not survive.

4. Describe the threat posed by invasive species and strategies resource managers use to slow their spread.

Teacher Preparation
Students will analyze possible human influences on the status of species found in the schoolyard ecosystem. Have students work individually or in small groups to collect data in the schoolyard ecosystem. If the schoolyard ecosystem is large, students could be assigned predetermined study areas. (See *Essential Activity 1.1*.)

At the end of this activity and during the discussion of possible solutions to negative human influences on species found in the schoolyard ecosystem, students should include some realistic solutions that they could accomplish. Have students discuss what they can do to make a difference.

Materials
Student science notebooks
Pencils
Nature Unbound student book (Figure 5.4 on p. 66)
Copies of *5.1 Schoolyard Ecosystem Chart* (optional)

Procedure
Part 1
1. Have students complete their science notebook headings.

2. In class, discuss the consequences of human activity in Missouri.

3. Create a Human Influences List including but not limited to:
   a. Pollution (acid rain, toxins, bacterial contamination, nutrient build up, trash, etc.)
   b. Habitat destruction, alteration, deforestation, fragmentation, homogenization
   c. Over harvest of resources
   d. Exploding urbanization
   e. Human affluence (*Note*: As affluence increases, there is an increase in the per capita resource use.)
   f. Introduction of exotic invasive species

4. Have students discuss positive influences and add them to their list. Include restoration of habitat if students do not include it.

Part 2
5. Have students copy the Human Influences List into their science notebooks.

6. In the schoolyard ecosystem, have students work individually or in small groups.

7. Students should list the species they observe and refer to the data collected in *Essential Activity 1.1*.
   a. Do they see the same species? Why or why not?

8. Students should create a chart similar to Figure 5.4 on page 66 of *Nature Unbound* or use the *5.1 Schoolyard Ecosystem Chart*:
   a. List species observed.
   b. Make best "guesses" as to whether each species would be at risk due to their traits:
      i. generalist vs. specialist
      ii. large population vs. small population
      iii. extensive range vs. restrictive range
   c. List human influences observed and the species affected by each.
   d. Include any invasive species observed.

9. Have each student or group report their findings from the schoolyard activity.

10. Have students list all human influences observed in the schoolyard ecosystem and compare and contrast human influences observed. For each negative human influence listed, have students discuss solutions and decide which of the suggested solutions they could actually accomplish. Prompt students to understand that solutions may be positive (or negative) influences on an environment. If a species found in the schoolyard ecosystem is considered an invasive, have students place a check in the last column.

Wrap up

1. Predict how schoolyard ecosystem species might be affected:
   a. If the school area was improperly sprayed with an insecticide.
   b. If a particular herbicide that acts as an Endocrine Disruptive Compound (disrupting hormonal balances) is used to control weeds in crop fields adjacent to an aquatic ecosystem.
      i. How might this affect species of fish and amphibians found in the local aquatic ecosystem?
      ii. What are the long-term effects on these species?
      iii. What could you as a member of the community do to alleviate this problem?

2. Bush honeysuckle is an invasive species brought to the United States from Asia as a benefit for wildlife. Since its introduction, it has aggressively colonized in most of Missouri. It competes for light and space with native species, thus reducing biodiversity.
   a. If left unchecked, what effects might bush honeysuckle have on the environment?
   b. What might be the effect:
      i. If the area were improperly sprayed with an herbicide?
      ii. If an Asian herbivore that eats bush honeysuckle were introduced into the environment?
   c. What are other possible solutions to this problem?

3. Compare extinctions today to mass extinctions in the past. Which of the five mass extinctions in the past is most like today's rate of extinction?

Assessment

1. Incorporate informal teacher assessment during class discussion and small group interactions.

2. Check for completion and accuracy of *5.1 Schoolyard Ecosystem Chart*.

Extensions

1. Form a Stream Team. Visit http://www.mostreamteam.org/.

2. Have a No MOre Trash pick-up day. Visit http://extra.mdc.mo.gov/nomoretrash/.

3. Have students research Missouri endangered, threatened and extirpated species and the Endangered Species Act.

5.1 Schoolyard Ecosystem Chart

Species	At risk? Yes/No	Potentially "Risky" Traits	Human Influences observed (Match with affected species.)	Invasive Species ✓

Essential Activity 5.2
Risks of Extinction

Estimated time
(2-3) 50-minute class periods
(Time will vary depending on amount of research done outside of class.)

Objectives
Students will be able to:
1. Describe traits that increase a species' risk of extinction.

2. Explain how the extinction of a species affects other species, including humans.

3. Explain why grassland bird populations are declining at an alarming rate and what resource managers are doing to increase grassland bird populations.

4. Form a testable question and hypothesis.

5. Analyze an experiment and identify the components.

Teacher Preparation
For this activity, students should refer to Chapter 5 of *Nature Unbound*, pages 64-67, and review "Ecology in Action—Giving Bobwhite Reproduction a Boost" on page 16. Have students work independently or in small groups. Students can access information on bobwhite quail, greater prairie-chickens and wild turkey at www.mdc.mo.gov. Internet searches will provide other useful links.

Materials
Student science notebooks
Pencils
Nature Unbound student book

Procedure
Part 1
1. Have students research bobwhite quail, greater prairie-chickens and wild turkey in Missouri.

2. From this research, have students predict which bird species will have a better survival rate over a ten-year period.

3. Students should:
    a. create data tables of population numbers for bobwhite quail, greater prairie-chickens and wild turkey
    b. use data tables to construct multi-line graphs
    c. interpret the data

4. The following questions should be used as prompts in student science notebooks:
    a. Was their prediction correct? Why or why not?
    b. Which species has a larger population? Why?
    c. Which species' population is increasing? Why?
    d. Which species' population is decreasing? Why?
    e. Is any species in danger of extinction? Explain.
    f. How might each species' niche, population and range affect its population numbers?
    g. Where would students place these species in Figure 5.4 on page 66 of *Nature Unbound*?
    h. How might other populations (coyote, bobcat, grasshoppers, various plants, etc.) be affected by fluctuating populations of wild turkey, bobwhite quail and greater-prairie chickens?
    i. How might people affect the populations of wild turkey, bobwhite quail and greater prairie-chickens?
    j. Have students research current methods used by MDC to manage and/or restore populations of wild turkey, bobwhite quail and greater prairie-chickens.

Part 2
1. Have students form a hypothesis concerning factors other than habitat that could cause the decline in population size of wild turkey, bobwhite quail or greater prairie-chickens.

2. Have students identify the independent and dependent variable.

3. Have students write a multi-step procedure for testing their hypothesis including at least three essential steps needed to conduct a valid experiment. Experiments should be written in such a way that other researchers (students) could reproduce it.

4. Have students create a data table to record findings.

Wrap up
1. Discuss student findings and experiments.

2. What other species could be investigated?

Assessment
Refer to *Appendix 1: Scoring Guide for Data Sheets* on page 213.

Extensions
1. Have students research species mentioned in the wrap up discussions.

2. Have students review a management plan.

Optional Activity 5A
Invasive Invasions

Estimated time
(2) 50-minute class periods

Objectives
Students will be able to:
1. Describe the threat posed by invasive species and identify strategies resource managers use to slow their spread.

2. Determine the appropriate tools and techniques to collect, analyze and interpret data.

Teacher Preparation
Students will monitor an area of the schoolyard ecosystem for invasive species using official emerald ash borer traps (contact the MDC Invasive Species Coordinator for information on obtaining these traps) and/or experimental traps designed by students. If students should discover one of the invasive species listed below trapped in one of the traps, they should submit their discovery to the appropriate agency and become part of statewide, national and/or international data collection.

At the same time, students will research the movement of an invasive species from one area (in Missouri/in North America/in the world) to another. Have students work in small groups, choose one of the invasive species listed below, plot its appearances on the appropriate map, predict the location of its next appearance, defend the prediction, hypothesize why this species appears where and when it does and offer a management suggestion to control the spread of this species.

Through their research, students should understand that these invasive species are transported by humans on their boats (zebra mussels), on waders and fishing equipment (Didymo) and in their firewood (most of the rest). These species hitchhike their way across the country. The spread of these can be slowed if people cleaned boats and all fishing equipment and gear carefully between bodies of water and burned their firewood where it was cut. Students may follow the results of the University of Missouri Japanese beetle trapping and monitoring program at http://ppp.missouri.edu/pestmonitoring/jb/index.cfm. Students may also reference www.dontmovefirewood.org and www.mdc.mo.gov for research.

Invasive Species
    Asian longhorn beetle
    Didymo
    Emerald ash borer
    Gypsy moth
    Japanese beetle
    Walnut twig beetle
    Zebra mussel

Materials

Student science notebooks
Pencils
Air thermometers
Emerald ash borer trap
Materials for student-made traps
Emerald ash borer detection kit
Insect field guides
Maps
Loupes/magnifiers
Forceps
Collection jars
Insect collection materials (optional)

Procedure

Part 1
1. Have students work in their groups and choose one of the following invasive species:
    a. Asian longhorn beetle
    b. Didymo
    c. Emerald ash borer
    d. Gypsy moth
    e. Japanese beetle
    f. Walnut twig beetle
    g. Zebra mussel

2. Groups should:
    a. Cite link(s) used for research on their chosen invasive species.
    b. Plot the appearances of their chosen invasive species on the appropriate map.
    c. Predict the location of the species' next appearance and defend the prediction.
    d. Hypothesize why this species appears where and when it does.
    e. Offer a management suggestion to control the spread of this species.

3. Have groups present their maps, predictions, hypotheses and management suggestions.

4. Groups should be prepared to defend their predictions and management suggestions.

Part 2
1. Have students review the natural history of the emerald ash borer, gypsy moth, Japanese beetle, walnut twig beetle and Asian longhorn beetle.

2. Have students work in small groups. Each group should:
    a. Choose one of the invasive species mentioned in Part 2 #1.
    b. Devise, create and label an experimental sticky trap for that species to be monitored by the group and/or label an official emerald ash borer trap.
    c. Place the trap or traps in the schoolyard ecosystem.
    d. Create a graphic organizer with the information listed in 6b on next page specific to each trap.

4. Each group will monitor its own trap(s).

5. Students should decide where the trap(s) should be placed.

6. Working in small groups and organizing a monitoring schedule, students should:
   a. Check the trap(s) at least once a day but more frequently, if possible.
   b. Create one graphic organizer maintained by all groups that includes the following for each monitoring session:
      i. Date
      ii. Time of day
      iii. Temperature
      iv. Weather conditions
      v. Common and scientific name of each species trapped
      vi. Number of each species trapped

7. At least once a week, have students discuss results from the monitoring of group traps:
   a. What species of insects were trapped in group traps?
   b. Compare and contrast the species trapped in each.
      i. Which traps contained the greater number of insects, the greater variety of species, etc.
      ii. Were certain species drawn to certain traps? Explain.
      iii. Were there characteristics (color, smell, shape, size, attractants, etc.) that affected the number of insects/species trapped? Explain.
   c. If the species trapped were invasive species, what strategies might a resource manager use to slow their spread based on student findings?

Wrap up

1. What caused the movement of each invasive species used in this activity? List these on the board.

2. What are the basic message(s) that might help people slow the spread of these invasive species?

Assessment

Refer to *Scoring Guide for Optional Activity 5A*.

Extensions

1. Plot the movement of an invasive plant species on a Missouri map.

2. Act as a marketing firm hired by the Missouri Department of Conservation to create a marketing campaign to help Missourians understand the harm caused by emerald ash borers, Didymo or zebra mussels and to teach Missourians what they can do to stop the spread of the species. Some potential marketing pieces might be a slogan, billboard design, public service announcement, television advertisement, YouTube segments, short jingle/song, etc. Present one or more pieces of each marketing campaign to the class and/or to middle and/or elementary school classes. Presentations could ultimately become part of the solution.

3. Begin a classroom insect collection. Insects found in traps could be identified, labeled and mounted in classroom collections. This activity could be ongoing and/or continue as long as there is student interest and insect activity.

Scoring Guide for Optional Activity 5A

Graphic organizer **(4 points)**
- 1 point for date, time of day and temperature
- 1 point for weather conditions
- 1 point for the common and scientific name of each species trapped
- 1 point for the number of each species trapped

Map **(1 point)**
- Check for accuracy.

Predictions **(1 point)**
- Predictions are defended and supported by data.

Hypothesis **(3 points)**
- The student correctly provides any reasonable hypothesis based on the testable question or statement of a problem that predicts an effect, or the lack of effect, of the independent variable on the dependent variable.

Management plan **(3 points)**
- Plan includes multi-step procedures toward achieving the goal.

Oral presentation **(1 point)**
- The student presents information orally with little difficulty.

Optional Activity 5B
Species of Conservation Concern

Estimated time
(2) 50-minute class periods

Objectives
Students will be able to:
1. Differentiate between extinction, extirpation, threatened, endangered and functionally extinct.

2. Identify and analyze how current theories on extinction compare and challenge older theories.

3. Identify species that have gone extinct or are at risk of extinction and the reasons for their possible extinction (pallid sturgeon, prairie-chicken, hellbenders).

4. Explain why specialists are more likely to go extinct than generalists.

Teacher Preparation
In this activity, students will work in small groups to research Missouri species that have become extinct, extirpated or are of conservation concern. To find information about species in Missouri that fit these categories, have groups search http://www.mdc.mo. Groups will create and present a poster or a brochure on their research. This activity can be done during class time or as homework.

Materials
Missouri Species and Communities of Conservation Concern
    (brochure or on Web at http://mdc.mo.gov/sites/default/files/resources/2010/04/4070_6135.pdf)
Missouri Plants of Conservation Concern
    (brochure or on Web at http://mdc.mo.gov/sites/default/files/resources/2010/04/4069_1692.pdf)
Missouri Animals of Conservation Concern
    (brochure or on Web at http://mdc.mo.gov/sites/default/files/resources/2010/04/4068_1693.pdf)
Information on Japanese beetle monitoring is found at
    http://ppp.missouri.edu/pestmonitoring/jb/index.cfm
Information on hellbenders, greater prairie-chickens and wolves is found at
    www.mdc.mo.gov
Poster board
Glue
Markers

Procedure

Part 1 Research

1. In small groups, have students research a species of their choice listed in *Missouri Species and Communities of Conservation Concern*.

2. Groups should prepare a poster or brochure which includes:
   - Name—common and scientific (*Genus species*)
   - Current status (state, federal, global)
   - Description (include a written description as well as one or more pictures)
   - Background (habitat, niche description, specialist/generalist, etc.)
   - Major cause(s) of status
   - Current steps to assist the species in recovery locally, federally (as mandated by the Endangered Species Act) and globally, as applicable

Note: Some species may be endangered in Missouri but not anywhere else. Presentation may be limited to a species of local concern.

Part 2 Presentations

1. Have groups present their posters.

2. As each group presents, discuss management techniques that are being used to assist the species in recovery and the pros and cons of these techniques.

Wrap up

1. Display group posters and brochures to promote future discussions.

Assessment

1. See *Scoring Guide for Posters for Optional Activity 5B*

2. See *Appendix 3: Scoring Guide for Oral Presentation* on page 215.

Scoring Guide for Posters for Optional Activity 5B

Endangered Species of Missouri Poster			
Item	**2**	**1**	**0**
Name	Common AND scientific names (*Genus* and *species*) are included.	Common name of an endangered species is identified.	None provided
Current Status	State AND federal endangered status is identified.	State or federal status is identified.	None identified
Description	Written description AND a picture is provided.	Description of species is provided but does not include any picture.	None provided
Background	Both habitat AND niche descriptions are provided.	A habitat description or niche description is provided.	None provided
Major Cause(s) of Endangerment	A complete description of the major cause(s) that placed this species on the endangered list is provided.	A partial description of the major cause(s) that placed this species on the endangered list is provided.	None provided
Steps toward Recovery	A complete description of the steps that are being taken on many levels that may lead to recovery of the species is provided.	A partial or incomplete description of the step(s) currently being taken to allow for recovery is provided.	None provided

Lesson 5
End of Chapter Assessment

1. How are the terms extinct, extirpated and endangered different? How are they similar? Define **and** give examples for each term.

2. Which statement explains why Carolina parakeets became extinct?
    a. The species is extirpated from Missouri due to habitat loss.
    b. The rising sea level caused the species to become extinct.
    c. Lewis & Clark overharvested the species while on the Corps of Discovery mission.
    d. Hunters shot the birds in large flocks and settlers overtook their habitat.

3. Compare and contrast the cause of previous mass extinctions with those of modern-day.

4. What are four possible causes of modern-day extinction of a species? What, if any, steps are being taken to reduce the impact of these causes?

5. How can the niche, population and range requirements of a species affect its ability to survive?

6. True or False. The extinction of a species affects other species, including humans. Explain your answer.

7. Which of the following actions might resource managers do in an attempt to restore habitat for grassland birds?
    a. Plant non-native vegetation.
    b. Encourage farmers to leave weedy borders around crop fields.
    c. Plan a prescribed fire.
    d. Both b and c

8. Non-native species such as the emerald ash borer, zebra mussel and sericea lespedeza spread rapidly and harm native species. List 3 strategies resource managers can utilize to control the spread of these invasive species.

9. Using information in the paragraph below, identify a testable question, hypothesis, independent variable and dependent variable.

> You have heard that prescribed fire is a management tool that increases biodiversity and you have noticed that agencies responsible for natural resource management use prescribed fires on their areas. You decide to conduct an experiment on your family's property, which includes a restored prairie. You conduct a survey on the entire prairie—identifying all plants, counting the number of species of plants (species richness) and estimating the number of individuals of each species (relative abundance). Then, you divide the prairie in half. On one half of the property, you plan and conduct periodic prescribed burns while on the other half you conduct no burns. After 10 years, you conduct a survey again, measuring species richness and relative abundance on each half. You compare the results of the burned half with the results of the non-burned half.

Testable question

Hypothesis

Independent variable

Dependent variable

Lesson 5
End of Chapter Assessment Scoring Guide

1. How are the terms extinct, extirpated and endangered different? How are they similar? Define **and** give examples for each term.
   Answer:
   Difference: Each term indicates the magnitude of loss.
   Similarity: All terms indicate a decrease in the population of a species within an area.

   Extinction is the complete elimination of an entire species.
   Extirpation is when a species disappears from one location but survives in another.
   Endangered is when a species is at risk of going extinct.

   Examples of extinct species include Carolina parakeet, passenger pigeon, woolly mammoth and dinosaurs.
   Examples of extirpated species in Missouri include wolves, bison and mountain lion.
   Examples of endangered species in Missouri include lake sturgeon, Mead's milkweed, Western chicken turtle, Hine's emerald dragonfly, and greater prairie-chicken **(8 points)**

2. Which statement explains why Carolina parakeets became extinct?
   a. The species is extirpated from Missouri due to habitat loss.
   b. The rising sea level caused the species to become extinct.
   c. Lewis & Clark overharvested the species while on the Corps of Discovery mission.
   d. Hunters shot the birds in large flocks and settlers overtook their habitat.
   Answer: d **(1 point)**

3. Compare and contrast the cause of previous mass extinctions with those of modern-day.
   Answer: Likely causes of previous mass extinctions include abiotic forces such as asteroid collisions, shifting continents, changes in sea levels, climate change or volcanic eruptions. Extinctions of today are more likely a result of biotic forces—specifically, human behaviors. **(4 points)**

4. What are four possible causes of modern-day extinction of a species? What, if any, steps are being taken to reduce the impact of these causes?
   Answer: Habitat destruction, competition with invasive species, overexploitation and climate change. Steps to reduce the impact might include the following: restoring native plants, paying farmers to leave weedy borders around fields, prescribed burning, applying herbicides, changing hunting seasons and regulations, developing new fuels, educating the public, conducting field research. **(5 points)**

5. How can the niche, population and range requirements of a species affect its ability to survive?
   Answer: Generalists, like deer, can survive in a wide range of environmental conditions and range of habitats, while specialists such as the Indiana bat can only survive in a few specific habitats and narrow range of environmental conditions. A large population of a species is less likely to be wiped out by disease than a species with a small population. Smaller populations also have less genetic variation and are less likely to find mates and group together for defense. Species that require a large geographic range have a greater buffer against environmental change than species that occupy a more restrictive geographic range. **(2 points)**

6. True or False. The extinction of a species affects other species, including humans. Explain your answer.
   Answer: True. Species maintain balance within biological communities by keeping other populations in check through competition, exploitation and mutualism. If too many species go extinct or are extirpated from a community, it isn't long before the community crashes. **(1 point)**

7. Which of the following actions might resource managers do in an attempt to restore habitat for grassland birds?
   a. Plant non-native vegetation.
   b. Encourage farmers to leave weedy borders around crop fields.
   c. Plan a prescribed fire.
   d. Both b and c

   Answer: d **(1 point)**

8. Non-native species such as the emerald ash borer, zebra mussel and sericea lespedeza spread rapidly and harm native species. List 3 strategies resource managers can utilize to control the spread of these invasive species.

   Answer:
   a. When outbreaks of the emerald ash borer are discovered, area quarantines are established.
   b. Resource managers can work to limit the spread of zebra mussels by encouraging boaters to use hot water to clean boats, motors and trailers and to let them dry in the sun for 5 days.
   c. Eradication of sericea lespedeza requires repeated treatments of a combination of burning, mowing and herbicide application. **(3 points)**

9. Using information in the paragraph below, identify a testable question, hypothesis, independent variable and dependent variable.

   > You have heard that prescribed fire is a management tool that increases biodiversity and you have noticed that agencies responsible for natural resource management use prescribed fires on their areas. You decide to conduct an experiment on your family's property, which includes a restored prairie. You conduct a survey on the entire prairie—identifying all plants, counting the number of species of plants (species richness) and estimating the number of individuals of each species (relative abundance). Then, you divide the prairie in half. On one half of the property, you plan and conduct periodic prescribed burns while on the other half you conduct no burns. After 10 years, you conduct a survey again, measuring species richness and relative abundance on each half. You compare the results of the burned half with the results of the non-burned half.

   Answer:
   Testable question: Do prairie plants respond to prescribed burns?
   Hypothesis: Prescribed fire increases species richness and relative abundance of plants on a restored prairie.
   Independent variable: Whether or not half of the prairie is burned
   Dependent variable: How prairie plant species and abundance changed in relation to the presence or absence of prescribed burns
   (4 points)

Lesson 6: Exploring the Nature of Energy Flow

Estimated time
(1-2) 50-minute class periods

Science CLEs

ME.1.I.a. Compare the mass of the reactants to the mass of the products in a chemical reaction or physical change (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, decomposition and synthesis reactions involved in a food web) as support for the Law of Conservation of Mass

ME.2.A. Forms of energy have a source, a means of transfer (work and heat) and a receiver

ME.2.F.a. ~~Classify the different ways to store energy (i.e., chemical, nuclear, thermal, mechanical, electromagnetic) and~~ describe the transfer of energy as it changes from kinetic to potential, while the total amount of energy remains constant within a system (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, food web)

EC.2.A. As energy flows through the ecosystem, all organisms capture a portion of that energy and transform it to a form they can use

EC.2.A.a. Illustrate and describe the flow of energy within a food web

EC.2.A.b. Explain why there are generally more producers than consumers in an energy pyramid

EC.2.A.c. Predict how the use and flow of energy will be altered due to changes in a food web

EC.2.B.b Explain the importance of the recycling of nitrogen, oxygen, and carbon within an ecosystem

IN.1.A.a. Formulate testable questions and hypotheses

IN.1.D.a. Communicate the procedures and results of investigations and explanations through:
- Oral presentations
- Drawings and maps
- Data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities)
- Graphs (bar, single and multiple line)
- Equations and writings

Vocabulary

Energy
Kinetic energy
Potential energy
Photosynthesis
Primary production
Cellular respiration
Producers
Energy flow
Consumers

Food chains
Slot length limit
Food web
Detritivores
Decomposers
Keystone species
Trophic level
Energy pyramids

Objectives

1. Define energy and distinguish between kinetic and potential.

2. Describe the transfer of energy as it changes from kinetic to potential, while the total amount of energy remains constant.

3. Explain why energy is important to organisms.

4. Describe how most organisms obtain the energy they need to survive.

5. Explain how primary production is affected by light, temperature, moisture and nutrients.

6. Illustrate and describe the flow of energy through a food chain.

7. Illustrate and describe the flow of energy through a food web, including detritivores and decomposers.

8. Predict the effects of removing species from a food web.

9. Define keystone species and explain their importance in maintaining balance in an ecosystem.

10. Explain how trophic levels are used to construct energy pyramids.

11. Explain why energy available to organisms decreases as it moves up trophic levels.

12. Explain why there are generally more producers than consumers in an energy pyramid.

Resource Management Objectives

1. Describe how resource managers use their knowledge of primary production and energy flow to stock fish in ponds.

2. Explain why knowledge of keystone species is important in habitat management plans.

Essential Questions

1. Why are there usually fewer than five levels in an energy pyramid?

2. What is the impact of changing a piece of a food web?

Teacher Notes

Students should read *Nature Unbound* Chapter 6 before beginning Lesson 6 activities.
    This lesson contains an outdoor activity that can be done in one or two class periods.

Outline of Answers to Objectives

See following page.

Essential Activities

Essential Activity 6.1—Caught in the Web
Essential Activity 6.2—Energy Pyramids

End of Chapter Assessment

Lesson 6 Questions and Answer Key

Summary

- Organisms need energy to grow, survive and reproduce.
- Most organisms obtain energy through photosynthesis or by eating other organisms.
- Primary production is affected by temperature, moisture and nutrients.
- Food chains show a specific pathway of energy flow in a community.
- Food webs are complex illustrations of interconnected food chains.
- Some species affect a food web more than others.
- Energy pyramids simplify food webs by sorting organisms into trophic levels.
- Only about five to twenty percent of energy passes from one trophic level to the next.

Outline of Answers to Objectives

1. **Define energy and distinguish between kinetic and potential.** (p. 70)
   a. Energy is defined as the ability to do work.
   b. Energy is grouped into two main categories of kinetic or potential.
      i. Energy in motion is called kinetic energy.
      ii. Potential energy is stored energy and has the potential to move.

2. **Describe the transfer of energy as it changes from kinetic to potential, while the total amount of energy remains constant.** (p. 70)
   a. Energy can't be created or destroyed but can change from one form into another. For example, water behind a dam is potential energy. Releasing some water to fill a lake changes the stored energy to kinetic energy.

3. **Explain why energy is important to organisms.** (p. 70)
   Everything an organism does requires energy. Life functions of organisms such as maintaining body temperature, escaping predators, growing new cells or pumping blood through the body all require energy.

4. **Describe how most organisms obtain the energy they need to survive.** (p. 71)
   a. Organisms get energy through consuming other organisms or through photosynthesis.
      i. Consumers get energy by eating other organisms.
      ii. Producers such as plants and photosynthetic organisms use kinetic energy from sunlight to combine molecules of water and carbon dioxide to produce glucose in the process of photosynthesis. Plant tissue is formed when glucose is combined with nitrogen and other elements to form proteins and nucleic acids. This process provides a form of energy that most organisms can use for growth, survival and reproduction and is called primary production.

5. **Explain how primary production is affected by light, temperature, moisture and nutrients.** (p. 72)
   a. The energy from sunlight is required for photosynthesis to occur. The rate of primary production is directly influenced by the amount of available sunlight. Limited amounts of sunlight limit the amount of primary production that occurs. Increased amounts of light produce an increase in the rate of primary production.
   b. The rate of primary production is influenced by temperature. When the temperature decreases, photosynthesis slows. As the temperature increases, the process of photosynthesis also increases (to a point). Photosynthesis generally occurs best from 16 degrees Celsius to 34 degrees Celsius.
   c. In the process of photosynthesis, molecules of water combine with carbon dioxide molecules to form glucose. Lack of water can hinder photosynthesis, which in turn, limits primary production.
   d. Nutrients such as nitrogen and phosphorus are required to form plant tissue. A lack of these elements can limit the growth of producers and the rate of primary production, particularly in aquatic ecosystems.

6. **Illustrate and describe the flow of energy through a food chain.** (p. 73)
    a. Food chains display the path of energy as it is transferred from producers to various consumers. As each organism is consumed, the energy is transferred into the tissues of the consumer.

7. **Illustrate and describe the flow of energy through a food web, including detritivores and decomposers.** (p. 75)
    a. A food web illustrates all the pathways the sun's energy might take as it is transferred from one organism to another in a community. Food webs show how food chains are interconnected and include detritivores and decomposers.
        i. Detritivores feed on dead organisms and excrete wastes. They break down dead organisms to smaller pieces. Examples of detritivores in a wetland are crayfish, worms and aquatic insects.
        ii. Decomposers feed on dead organisms and break down the nutrient molecules found in the organisms' tissues into simpler molecules that can be used by producers during photosynthesis. Examples of decomposers are bacteria and fungi.

8. **Predict the effects of removing species from a food web.** (p. 76)
    a. When one organism is removed from a community, all the organisms that eat that particular organism plus the organisms higher on the food chain will be greatly impacted. For example, if algae disappears from a wetland, snails and crayfish would be affected. In addition, the organisms that eat snails and crayfish would be affected.
    b. If a keystone species is removed, the flow of energy through the community will be greatly affected in various ways. For example, removing muskrats from a marsh will allow the cattails to dominate the marsh, and plant diversity will be diminished.

9. **Define keystone species and explain their importance in maintaining balance in an ecosystem.** (pp. 76-78)
    a. Species that have a stronger influence than other species on the way energy flows through a food web are referred to as keystone species.
    b. The loss of a keystone species in an ecosystem has a greater consequence on the flow of energy than the loss of other, less influential species.

10. **Explain how trophic levels are used to construct energy pyramids.** (p. 78)
    a. Trophic levels group organisms by the position they occupy in a food chain. Energy pyramids depict the amount of energy available at each trophic level. The shape of the pyramid shows that consumers at higher trophic levels have less energy to support them than consumers at lower trophic levels.
        i. The first level contains producers that convert the sun's energy into other usable forms of energy.
        ii. The second trophic level contains primary consumers—organisms that eat primary producers.
        iii. The third trophic level contains secondary consumers that eat primary consumers.
        iv. The fourth trophic level contains tertiary consumers that eat secondary consumers.
        v. The fifth trophic level is made up of quaternary consumers that eat tertiary consumers.

11. **Explain why energy available to organisms decreases as it moves up trophic levels.** (pp. 79-80)
    a. At the first trophic level, 15% of the sun's energy goes back to the atmosphere, 40% is converted to heat, 40% is used to move water through the plant, 4% is used for cellular reproduction and only 1% becomes available to primary consumers.
    b. At the second trophic level, some tissue can't be used and is excreted as waste; other digested tissue is used in cellular respiration or is lost as heat.
    c. Generally, only 5 to 20 percent of the total energy is passed to the next trophic level. The major portion of the energy is lost due to the following three reasons:
        i. The inability of organisms to digest certain tissues from organisms in a lower trophic level
        ii. The use of energy to keep the organism alive
        iii. The loss of energy as heat transferred to the environment

12. **Explain why there are generally more producers than consumers in an energy pyramid.** (p. 81)
    a. Primary producers generally outnumber consumers because producers support the consumers at all levels of the energy pyramid. Energy is lost as it moves through each trophic level, making less energy available to higher-level consumers. A greater number of producers is required to support the next trophic level. This explains why most food chains have five or fewer links.

Resource Management Objectives

1. **Describe how resource managers use their knowledge of primary production and energy flow to stock fish in ponds.** (p. 74)
   a. A pond's most important producers are microscopic plants called phytoplankton. Phytoplankton require carbon dioxide, water, sunlight and nutrients such as nitrogen and phosphorous. These nutrients wash from the soil and dissolve in pond water. In areas with high soil fertility there are more nutrients available, and primary production by phytoplankton is higher. Resource managers use information about the fertility of soils to identify the ideal amounts and variety of fish for stocking a pond. Richer soils can support higher levels of fish because the primary production will be higher. Soils with poor fertility will not support the same level of fish.
   b. Ponds often contain an overabundance of bass 20 to 30 centimeters in length. Biologists call this a stockpiled bass population. The bass get just enough food to stay alive, but not enough to grow very large. In this situation, resource managers may encourage increasing bass harvest by instituting a slot length limit. The length limit allows fish under and over a certain length, or slot, to be harvested. A slot length limit between 30 and 40 centimeters would encourage harvest of bass less than 30 centimeters and over 40 centimeters. All fish between 30 and 40 centimeters are released. Removing a large number of smaller bass makes more food available to the remaining fish.

2. **Explain why knowledge of keystone species is important in habitat management plans.** (p. 77)
   Knowledge of keystone species, like the prairie lizard (formerly known as the Northern fence lizard) on glades, will determine how to manage the habitat to promote that species and restore the community.

Essential Activity 6.1
Caught in the Web

Estimated time
(1-2) 50-minute class periods

Objectives
Students will be able to:
1. Describe how most organisms obtain the energy they need to survive.

2. Illustrate and describe the flow of energy through a food chain.

3. Illustrate and describe the flow of energy through a food web, including detritivores and decomposers.

4. Predict the effects of removing various pieces of a food web.

5. Define keystone species and explain their importance in maintaining balance in an ecosystem.

6. Explain how trophic levels are used to construct energy pyramids.

7. Explain why energy available to organisms decreases as it moves up trophic levels.

8. Explain why there are generally more producers than consumers in an energy pyramid.

Teacher Preparation
Have students work in groups of three or four to create food webs adding information they collect about decomposers and detritivores. The final project will be to create an energy pyramid.

Locate several different habitats in the schoolyard ecosystem. Assign groups to specific habitats to ensure all are represented. Discuss collection techniques with students. Discuss the pros and cons of (1) collecting specimens to take back to the classroom for identification and (2) recording organisms and releasing them immediately. Remind students that it is best to observe an area before disturbing it. Many animals will move away once they are disturbed. Moving into and observing an area quietly will improve and increase opportunities to observe organisms.

Materials
Student science notebooks
Pencils
Air thermometer
Insect nets
Forceps
Collection jars
Magnifiers
6.1 Investigation Cards (6 or 7 per student)
Field guides
Poster board
Yarn
Digital cameras and/or the camera feature of cell phones (*optional*)

Procedure

Part 1

1. Have students complete their science notebook headings and record questions they have during the activity.

2. Provide each student five *6.1 Investigation Cards*. Remind students that not all organisms need to be collected but that all organisms should be observed, described, recorded and placed in a trophic level.

3. Instruct students to begin by carefully observing their study area before they disturb it. Many organisms can be observed by quiet observation.

4. Divide students into small groups. Groups should be assigned to different habitats of the study site. Each student's set of five cards should represent the five different trophic levels. Move among groups and provide prompts to groups that are not including producers as organisms.

5. Students should complete their cards. If the common name of an organism isn't known, students should record distinguishing characteristics. Digital cameras may be used to record organisms and their characteristics. If an organism is collected, students should record the jar label number in the blank for the name.

6. Students should record any observations which may be helpful in identifying the organism's trophic level and relationship to other organisms in its food web. If necessary, include these prompts:
   a. Did you observe the organism collecting energy?
   b. Was the organism in a predator or prey role?
   c. Did you observe the organism interacting or associating with another organism?

Part 2

1. Have groups arrange their cards in a food chain. If necessary, provide prompts to ensure students have identified five trophic levels in each food chain.

2. Provide each group with one or two more *6.1 Investigation Cards*. Groups should return to their study area to look for decomposers and complete a card for any decomposers observed.

3. Groups should arrange their cards to create a food web. If necessary, provide prompts to remind students to include decomposers and/or detritivores.

4. In the classroom, each group should create a food web on poster board that depicts their habitat using digital photos or investigation cards. Yarn may be used to illustrate the numerous pathways through which energy flows among organisms.

5. Each group should present their energy pyamids to the class. Presentations should address the following questions:
   a. Are there organisms that are likely to be in the food web but were not observed?
   b. Is one organism more connected than others (keystone species)?
   c. What would happen if that organism (keystone species) were removed from the habitat?
   d. What would happen if half of the producer species were removed? What if 75% were removed?
   e. What might cause such a loss of producers and what implications might this have on individual organisms and on the entire habitat? How might this effect energy flow?
   f. In their schoolyard ecosystem, what human influences (positive and/or negative) affect the food web they presented?
   g. What questions do students have about their observations?

6. Display the food webs.

7. Students should compile information from the food webs to create a schoolyard ecosystem energy pyramid indicating where the energy goes. (See Figure 6.5 on page 80 of *Nature Unbound*.)

Wrap up

1. Review and discuss student findings.

2. List student questions and have students decide which questions are testable.

3. Discuss how they would create an experiment, field study or further observation on one of the testable questions.

Assessment

1. Check for completion and accuracy of investigation cards and energy pyramid.

Extensions

1. Predict food chains and food webs found in different habitats.

2. Create a poster, PowerPoint, etc. of these food chains or food webs.

3. Identify keystone species for each habitat.

6.1 Investigation Card

Habitat (name or description): _____

_____

Common Name/Description/Collection Jar Number: _____

_____

_____

Scientific Name: _____

Trophic Level: _____

Energy Source:_____

Who consumes this organism?_____

Use back of Investigation Card for other observations.

Question: _____

_____

6.1 Investigation Card

Habitat (name or description): _____

_____

Common Name/Description/Collection Jar Number: _____

_____

_____

Scientific Name: _____

Trophic Level: _____

Energy Source:_____

Who consumes this organism?_____

Use back of Investigation Card for other observations.

Question: _____

_____

Essential Activity 6.2
Energy Pyramids

Estimated Time
(1) 50-minute class period

Objectives
Students will be able to:
1. Illustrate and describe the flow of energy.

2. Explain how trophic levels are used to construct energy pyramids.

3. Explain why energy available to organisms decreases as it moves up trophic levels.

4. Explain why there are generally more producers than consumers in an energy pyramid.

Teacher Preparation
A large outdoor area will be needed for this activity. This activity will illustrate that, on average, ten percent of energy consumed is converted to bodily use and 90% is lost. The numbers used are arbitrary, but the percentage represents an average loss over various ecosystems. In the modified ecosystem on the student worksheet, the numbers are smaller to make the paper pyramid more manageable. In an actual ecosystem, the numbers are larger, reflecting a more accurate description of the energy in an ecosystem, but the paper needed would be immense. It may only be necessary for students to see this and not actually follow through on the construction of the actual ecosystem, or one model may be made with the entire class.

Have students work in groups of three or four to create visual representations of energy pyramids. Using the worksheet as a guide, groups will build paper pyramids which indicate energy loss at each trophic level. The final product will be the pyramids.

Materials
Student science notebooks
Pencils
Rolls of adding machine paper or toilet paper
Copies of *6.2 Energy Pyramid Worksheet* (one per group)
Calculators
Scissors
Colored markers
Poster board or butcher paper
Metric rulers and/or metric measuring tapes

Procedure

1. Have students complete their science notebook headings.

2. Have groups complete the *6.2 Energy Pyramid Worksheet* for the modified and actual ecosystems. Explain that in the modified ecosystem, the numbers are arbitrary but percentages are accurate for most ecosystems. At each trophic level, the lengths are multiplied by .1 (indicating 10% of the energy is available from the previous trophic level).

3. Have groups cut four pieces of adding machine paper or toilet paper, the length of each strip of paper should reflect the length of one of the four trophic levels as determined on the worksheet. These four strips of paper represent the four trophic levels of the modified energy pyramid. On a large piece of poster board or butcher paper, have groups place the strip of paper representing the producers on the bottom, then the primary consumers, secondary consumers, and finally, the tertiary consumers on top. Label and decorate (with examples of organisms) for each level of this pyramid.

4. Have groups repeat step 2 for the actual energy pyramid. Numbers will be larger, so the lengths of paper will be longer.

5. Have students display the pyramid on the ground. When completed, lay the modified pyramid next to it for comparison.

6. Have students summarize what they have learned in their science notebooks.

Wrap up

1. Discuss student findings and summaries.

2. Discuss what would happen if the producer level were decreased by 50%. What might cause such a loss, and what implications might this have on the energy flow through the entire ecosystem?

3. Display modified pyramids. Did students use examples from the same ecosystem?

Assessment

1. Check pyramids for completion and accuracy.

2. Check summaries in science notebooks for understanding.

Extension

1. Cave animals can only convert 2.5% of the energy for bodily use. Using that number (.025), have students create an energy pyramid for caves.

6.2 Energy Pyramid Worksheet

Directions: Fill in the worksheet, starting with the modified ecosystem. These numbers are arbitrary. At each level, use the number from the previous level in your calculations. Then, measure pieces of adding machine paper or toilet paper to represent each trophic level. Glue the levels onto a large piece of poster board or butcher paper, starting with producers on the bottom, then primary, secondary and finally, tertiary consumers. Decorate the paper with pictures or labels of plant and animal examples at each trophic level.

MODIFIED ECOSYSTEM

    1st level—Producers: 640 mm

    2nd level—Primary consumers: (640 mm X 0.1) = _____ mm

    3rd level—Secondary consumers:　　(_____ mm X 0.1) = _____ mm

    4th level—Tertiary consumers:　　(_____ mm X 0.1) = _____ mm

ACTUAL ECOSYSTEM
(with actual energy base 200X greater than the modified ecosystem)

    1st level—Producers: (640 mm X 200) = _____ mm

    2nd level—Primary consumers:　　(_____ mm X 0.1) = _____ mm

    3rd level—Secondary consumers:　　(_____) mm X 0.1 = _____ mm

    4th level—Tertiary consumers:　　(_____) mm X 0.1 = _____ mm

Lesson 6
End of Chapter Assessment

1. Which statement below describes energy?
   a. Energy is the raw material that creates change.
   b. Energy is required for organisms to grow new cells.
   c. Organisms can transform one form of energy into another.
   d. Energy is the ability to do work.
   e. All of the statements describe energy.

2. Which of the following statements provides an example of how energy is changed from kinetic to potential energy?
   a. A cell phone transforms the chemical energy in its batteries into electricity.
   b. A tree uses the sun's energy to transform water and carbon dioxide into glucose.
   c. Light waves produce heat.
   d. During cellular respiration, oxygen and glucose react to form carbon dioxide and water.

3. Give an example to explain how the total amount of energy remains constant within a system during the transfer of energy from kinetic to potential.

4. Explain how energy is important to organisms.

5. List two ways organisms obtain the energy they need to survive.

6. Formulate a testable question concerning primary production of an ecosystem. What variables might affect the rate of primary production?

7. Draw and label a diagram to illustrate the flow of energy through a food chain.

8. Explain the function of decomposers and detritivores in a food web.

9. Define a keystone species.

10. Suppose muskrats are overharvested from a wetland ecosystem. Predict how the use and flow of energy would be altered.

11. Which of the following statements explains why an energy pyramid generally has more producers than consumers?
    a. Energy is lost as it moves through each trophic level, making less energy available to higher-level consumers.
    b. When a producer is removed from a community, all the organisms that eat that particular organism plus the organisms higher on the food chain will be negatively impacted.
    c. Consumers at higher trophic levels have more energy than consumers at lower trophic levels.
    d. Almost 90% of the energy in the first trophic level is transferred to primary consumers.

12. Give examples of organisms at each trophic level and explain why they belong at that level.

13. Which of the following helps to explain why the amount of energy available to an organism decreases as it moves up trophic levels?
    a. The inability of the organism to digest certain tissues from organisms in a lower trophic level causes the energy to become fuel for decomposers.
    b. An organism uses some of the energy for life functions.
    c. As energy is transferred, some is lost as heat into the environment.
    d. All of the above

14. What actions might a resource manager take to resolve the problem of a pond with an overabundance of small bass?

Lesson 6
End of Chapter Assessment Scoring Guide

1. Which statement below describes energy?
    a. Energy is the raw material that creates change.
    b. Energy is required for organisms to grow new cells.
    c. Organisms can transform one form of energy into another.
    d. Energy is the ability to do work.
    e. All of the statements describe energy.
    Answer: e **(1 point)**

2. Which of the following statements provides an example of how energy is changed from kinetic to potential energy?
    a. A cell phone transforms the chemical energy in its batteries into electricity.
    b. A tree uses the sun's energy to transform water and carbon dioxide into glucose.
    c. Light waves produce heat.
    d. During cellular respiration oxygen and glucose react to form carbon dioxide and water.
    Answer: b **(1 point)**

3. Give an example to explain how the total amount of energy remains constant within a system during the transfer of energy from kinetic to potential.
    Answer: In the process of photosynthesis, plants obtain kinetic energy from sunlight. The energy doesn't disappear but is changed into different forms. The plant loses part of the energy as heat, and part is transformed into the potential energy of glucose. Another part of the energy is released into the atmosphere. The amount of energy did not change. **(4 points)**

4. Explain how energy is important to organisms.
    Answer: Organisms require energy to complete functions necessary for life. Those functions include maintaining body temperature, growing new cells, pumping blood through the body and escaping predators. **(4 points)**

5. List two ways organisms obtain the energy they need to survive.
    Answer: Organisms get energy through consuming other organisms or through photosynthesis. **(2 points)**

6. Formulate a testable question concerning primary production of an ecosystem. What variables might affect the rate of primary production?
    Answers will vary but should include one of the following factors: Light, temperature, moisture or nutrients. (2 points)

7. Draw and label a diagram to illustrate the flow of energy through a food chain.
    Answer: Diagrams will vary, but should include the path of energy beginning with producers and the transfer to various consumers. **(1 point)**

8. Explain the function of decomposers and detritivores in a food web.
    Answer:
    a. Decomposers feed on dead organisms and break down the nutrient molecules found in the organisms' tissues into simpler molecules that can be used by producers during photosynthesis. Examples of decomposers are bacteria and fungi.
    b. Detritivores get their energy by feeding on dead organisms and provide energy by excreting wastes. Examples of detritivores in a wetland are crayfish, worms and aquatic insects. **(4 points)**

9. Define a keystone species.
   Answer: Keystone species are usually one of the least abundant organisms in a community but have a disproportionate effect on the way energy flows through the community. **(1 point)**

10. Suppose muskrats are overharvested from a wetland ecosystem. Predict how the use and flow of energy will be altered.
    Answer:
    a. When one organism is removed from a community, all the organisms that eat that particular organism plus the organisms higher on the food chain will be negatively impacted.
    b. If a keystone species is removed, the flow of energy through the community will be adversely affected in various ways. For example, removing muskrats from a marsh will allow the cattails to dominate the marsh, and plant diversity will be diminished. **(2 points)**

11. Which of the following statements explains why an energy pyramid generally has more producers than consumers?
    a. Energy is lost as it moves through each trophic level, making less energy available to higher-level consumers.
    b. When a producer is removed from a community, all the organisms that eat that particular organism plus the organisms higher on the food chain will be negatively impacted.
    c. Consumers at higher trophic levels have more energy than consumers at lower trophic levels.
    d. Almost 90% of the energy in the first trophic level is transferred to primary consumers.
    Answer: a **(1 point)**

12. Give examples of organisms at each trophic level and explain why they belong at that level.
    Answer: Producers should include plants and other organisms that use photosynthesis to convert sunlight into chemical energy. Primary consumers should include herbivores that eat the producers. Secondary consumers should include omnivores and carnivores that eat the primary consumers. The fourth trophic level should include tertiary consumers that eat secondary consumers. The fifth trophic level should include quaternary consumers that eat tertiary consumers. **(4 points)**

13. Which of the following helps to explain why the amount of energy available to an organism decreases as it moves up trophic levels?
    a. The inability of the organism to digest certain tissues from organisms in a lower trophic level causes the energy to become fuel for decomposers.
    b. An organism uses some of the energy for life functions.
    c. As energy is transferred, some is lost as heat into the environment.
    d. All of the above
    Answer: d **(1 point)**

14. What actions might a resource manager take to resolve the problem of a pond with an overabundance of small bass?
    Answer: Ponds often contain an overabundance of bass 20 to 30 centimeters in length. Biologists call this a stockpiled bass population. The bass get just enough food to stay alive, but not enough to grow very large. In this situation, resource managers may encourage increasing bass harvest by instituting a slot length limit. The length limit allows fish under and over a certain length, or slot, to be harvested. A slot length limit between 30 and 40 centimeters would encourage harvest of bass less than 30 centimeters and over 40 centimeters. All fish between 30 and 40 centimeters are released. Removing a large number of smaller bass makes more food available to the remaining fish. **(1 point)**

Lesson 7: The Cycling of Elements Through Ecosystems

Estimated time
(3) 50-minute class periods

Science CLEs

ME.1.I.a. Compare the mass of the reactants to the mass of the products in a chemical reaction or physical change (e.g., biochemical processes, carbon dioxide-oxygen cycle, nitrogen cycle, decomposition and synthesis reactions involved in a food web) as support for the Law of Conservation of Mass

EC.2.B.a. Explain the processes involved in the recycling of nitrogen, oxygen, and carbon through an ecosystem

EC.2.B.b. Explain the importance of the recycling of nitrogen, oxygen, and carbon within an ecosystem

EC.3.C.c. Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection

EC.3.C.d. Given a scenario describing an environmental change, hypothesize why a given species was unable to survive

IN.1.A.a. Formulate testable questions and hypotheses

IN1.A.b. Analyzing an experiment, identify the components (i.e., independent variable, dependent variables, control of constants, multiple trials) and explain their importance to the design of a valid experiment

IN1.A.c. Design and conduct a valid experiment

IN.1.B.a. Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., ~~microscopes~~, thermometers, analog and digital meters, computers, ~~spring scales~~, ~~balances~~, metric rulers, ~~graduated cylinders~~)

IN.1.B.b. Measure length to the nearest millimeter, mass to the nearest gram, volume to the nearest milliliter, force (weight) to the nearest Newton, temperature to the nearest degree Celsius, time to the nearest second

IN.1.C.a. Use quantitative and qualitative data as support for reasonable explanations (conclusions)

IN1.C.b. Analyze experimental data to determine patterns, relationships, perspectives, and credibility of explanations (e.g., predict/extrapolate data, explain the relationship between the independent and dependent variable)

IN.1.C.c. Identify the possible effects of errors in observations, measurements, and calculations, on the validity and reliability of data and resultant explanations (conclusions)

IN.1.D.a. Communicate the procedures and results of investigations and explanations through:
      Oral presentations
      Drawings and maps
      Data tables (allowing for the recording and analysis of data relevant to the experiment such as independent and dependent variables, multiple trials, beginning and ending times or temperatures, derived quantities)
      Graphs (bar, single, and multiple line)
      Equations and writings

Vocabulary

Element cycling
Chemical elements
Molecule
Compound
Biomolecules
Pools
Reservoirs
Biosphere
Geosphere
Hydrosphere
Atmosphere
Law of conservation of matter
Geological carbon cycle
Biological carbon cycle
Mycorrhizae

Mycelia
Nitrogen fixation
Nitrification
Anaerobic
Denitrification
Water cycle
Evaporation
Transpiration
Condensation
Precipitation
Aquifers
Runoff
Eutrophication
Greenhouse gases

Objectives

1. Distinguish between atom, element, molecule and compound.

2. Identify which elements are essential for life.

3. Identify the pools and reservoirs in which atoms reside in ecosystems.

4. Describe how physical and chemical processes move atoms from one pool or reservoir to another.

5. Explain the law of conservation of matter.

6. Explain the processes involved in the carbon cycle.

7. Explain the processes involved in the phosphorus cycle.

8. Explain the processes involved in the nitrogen cycle.

9. Explain the processes involved in the water cycle.

10. Describe ways humans affect the cycling of elements through ecosystems.

11. Explain the importance of the recycling of elements within an ecosystem.

Resource Management Objectives

1. Explain why lead is harmful to organisms and describe steps resource managers take to reduce its occurrence in ecosystems.

Essential Questions

Which molecules does life demand, and how are they supplied?

Teacher Notes

Students should read *Nature Unbound* Chapter 7 before beginning Lesson 7 activities.

Essential Activity 7.2 requires soil and/or water test kits. If these are not available, arrange to borrow them from the local Missouri Department of Conservation Education Consultant. Before using soil and/or water test kits, review with students how such kits are used and safety guidelines for each.

Outline of Answers to Objectives

See following page.

Essential Activities

Essential Activity 7.1—Element Journeys
Essential Activity 7.2—Testing for Elements

End of Chapter Assessment

Lesson 7 Questions and Answer Key

Summary

- All matter is composed of atoms.
- Physical and chemical processes move atoms through ecosystems.
- Atoms cannot be created or destroyed.
- Atoms follow specific pathways through ecosystems.
- Human populations affect element cycles.

Outline of Answers to Objectives

1. **Distinguish between atom, element, molecule and compound.** (*Nature Unbound*, p. 84)
   a. Atom—All matter is composed of atoms.
   b. Element—Elements can combine to form molecules and compounds.
   c. Molecule—A molecule is formed when two or more atoms combine.
   d. Compound—A compound is a molecule that contains at least two different elements.

2. **Identify which elements are essential for life.** (pp. 84-85)
   Oxygen, Carbon, Hydrogen, Phosphorus, Nitrogen

3. **Identify the pools and reservoirs in which atoms reside in ecosystems.** (p. 85)
   a. Pools—Pools are places where atoms collect for a short length of time (from a few hours to a few years).
   b. Reservoirs—Reservoirs are places where atoms reside for longer periods of time (decades to millions of years).

4. **Describe how physical and chemical processes move atoms from one pool or reservoir to another.** (p. 85)
   a. Physical process—*Ex.* When water evaporation occurs, hydrogen and oxygen atoms move from the hydrosphere to the atmosphere.
   b. Chemical Process—*Ex.* During photosynthesis, hydrogen and oxygen in plants are chemically rearranged to form various molecules that make up the tissues of plants. Hydrogen and oxygen are being moved by a chemical process from the hydrosphere, atmosphere or geosphere into living things (biosphere).

5. **Explain the law of conservation of matter.** (p. 86)
   Matter cannot be created or destroyed. Atoms are simply recycled and reused over and over again.

6. **Explain the processes involved in the carbon cycle.** (pp. 86-88)
   a. Carbon is the frame upon which every molecule used by living things is built.
   b. Geological Carbon Cycle—It takes millions of years for carbon to make the round trip through this cycle. Carbon moves among the geosphere, atmosphere and hydrosphere.
   c. Biological Carbon Cycle—It is closely tied to the flow of energy through ecosystems. Producers absorb carbon dioxide from the air or water and convert it through photosynthesis into carbohydrates. Producers store a portion of these carbohydrates in their tissues. Consumers ingest these carbohydrates. Most carbon leaves the biosphere through cellular respiration. Carbon can also leave the biosphere through decomposition and fire.

7. **Explain the processes involved in the phosphorus cycle.** (p. 89)
   a. Phosphorus helps form DNA, RNA and the energy molecule ATP. It is a structural component of cell membranes, bones and teeth.
   b. The largest reservoir of phosphorus is sedimentary rocks. Rain removes phosphorus in the form of phosphate from these rocks and washes it into the soils and hydrosphere where it can be used by organisms. Phosphorus moves into the food chain when plants absorb phosphate through their roots. Other organisms obtain phosphorus by eating plants and other organisms. Decomposition returns phosphate to the soil.

8. **Explain the processes involved in the nitrogen cycle.** (pp. 90-91)
   a. Nitrogen is an essential part of DNA, RNA and amino acids. It helps form chlorophyll.
   b. The major reservoir of the Earth's nitrogen is the atmosphere. Seventy-eight percent of the air we breathe is nitrogen gas (N_2). Few organisms can use nitrogen in this form so it must undergo a process called nitrogen fixation which changes nitrogen gas into ammonia. Plants use ammonia to make proteins and other nitrogen based molecules. Nitrogen is thus incorporated into the food chain. When organisms die or excrete wastes, decomposers convert the nitrogen compounds in their bodies or wastes back into ammonia.

9. **Explain the processes involved in the water cycle.** (pp. 92-93)
    a. The water molecule is one of the most important ingredients of life. Water is the basis of fluids such as blood and cytoplasm. Water plays an important role in reproduction. Water is also a key habitat component for a vast array of organisms.
    b. The water cycle is the movement of water through different spheres. Some water moves between the biosphere and other spheres through the chemical reactions that occur inside organisms. Most of the water cycle, however, is driven by physical factors—solar energy and gravity.
    c. Evaporation moves water from the geosphere and hydrosphere to the atmosphere. Living organisms also move water from the biosphere to the atmosphere. Water vapor condenses in the atmosphere and falls as precipitation to the hydrosphere and geosphere.

10. **Describe ways humans affect the cycling of elements through ecosystems.** (pp. 93-94)
    a. Human activity has increased the amount of nitrogen and phosphorus in the biosphere. Creating nitrogen and phosphorus fertilizers has led to too much of these elements in ecosystems. When large amounts of fertilizers run off the land into watersheds, eutrophication can occur. This depletes the oxygen in the water causing the aquatic ecosystem to collapse.
    b. Deforestation and burning of fossil fuels results in large quantities of carbon being put into the atmosphere. Carbon-based gases (greenhouse gases) allow sunlight to pass through but trap heat. This is called the greenhouse effect which is important in creating earth's temperatures. However, these gases are building up at an alarming rate which has scientists concerned about global climate change.
    c. Humans also affect the distribution of water through consumption and pollution.

11. **Explain the importance of the recycling of elements within an ecosystem.** (p. 86; p. 93)
    Because of gravity and the conservation of matter, the Earth is a closed system. Elements provide the basis for life and are recycled, reused and rearranged. They must move through an ecosystem so that they can be utilized.

Resource Management Objectives

1. Explain why lead is harmful to organisms and describe steps resource managers take to reduce its occurrence in ecosystems. (p. 95)
    a. Lead is toxic even in small concentrations. It causes irreparable bone, nerve and muscle damage. Animals exposed to lead may starve to death, become easy prey or pass lead up the food chain where it will kill other animals.
    b. Resource managers have taken steps to reduce lead in ecosystems by banning lead shot for waterfowl hunting. This reduces the amount of lead in aquatic ecosystems.

Essential Activity 7.1
Element Journeys

Estimated Time
(1) 50-minute class period

Objectives
Students will be able to:
1. Recognize that an ecosystem involves interactions among the abiotic and biotic parts of the earth.

2. Identify the pools and reservoirs in which atoms reside in ecosystems.

3. Describe how physical and chemical processes move atoms from one pool or reservoir to another.

4. Explain the processes involved in the carbon/oxygen cycle.

5. Explain the processes involved in the phosphorus cycle.

6. Explain the processes involved in the nitrogen cycle.

7. Explain the processes involved in the water cycle.

8. Describe ways humans affect the cycling of elements through the ecosystem.

9. Explain the importance of recycling of carbon, oxygen, phosphorus and nitrogen within an ecosystem.

Teacher Preparation
Have students work independently in the schoolyard ecosystem to create a descriptive cycle of nitrogen, carbon, phosphorus or water through the schoolyard ecosystem. Students should first read "Odyssey" from Aldo Leopold's *Sand County Almanac*. In this essay, Aldo Leopold traces two generic nutrients, X and Y, as they cycle through an ecosystem. Have students use this as an example to create their own essay about one of the element cycles or the water cycle. Have students include one example of how humans influence the cycle. Students should have their student book for this activity and reference Figure 7.3, "The Geological Carbon Cycle," Figure 7.4, "The Biological Carbon Cycle," Figure 7.5, "The Phosphorus Cycle," Figure 7.6, "Physical and Biological Components of the Nitrogen Cycle." Figure 7.7, "The Water Cycle," and Ecology in Action, "Keeping Harmful Elements Out of Ecosystems," p. 95.

Materials
Student science notebook
Pencils
Air thermometer
"Odyssey" from Aldo Leopold's *Sand County Almanac*
Nature Unbound student book

Procedure

1. Have students complete headings in their science notebooks.

2. Have students read "Odyssey" from *Sand County Almanac* by Aldo Leopold.

3. Give students boundaries and a time limit.

4. Remind students that they must have at least one human influence in their cycle.

5. Allow them to spread out to make observations to create their essay. They only need to write about one cycle.

Wrap up

1. Have students share their essays.

2. Have students discuss the human influences they used in their cycle.

3. Have students discuss Ecology in Action, "Keeping Harmful Elements Out of Ecosystems," p. 95.

4. What are sources of lead in Missouri? How does it enter the environment? What problems might it cause? What steps are being taken to reduce its occurrence in ecosystems?

Assessment

Refer to *Appendix 4: Scoring Guide for Science Writing* on page 216.

Extension

1. Research lead pollution in Missouri.

Essential Activity 7.2
Testing for Elements

Estimated Time
(2) 50-minute class periods

Objectives
Students will be able to:
1. Recognize that an ecosystem involves interactions among the abiotic and biotic parts of the earth.

2. Identify the pools and reservoirs in which atoms reside in ecosystems.

3. Explain the processes involved in the phosphorus cycle.

4. Explain the processes involved in the nitrogen cycle.

5. Explain the importance of recycling of carbon, oxygen, phosphorus and nitrogen within an ecosystem.

Teacher Preparation
This activity will allow students to determine places in the schoolyard ecosystem where elements from the cycles reside. They will investigate the nitrogen and phosphorus cycles. Students will be given a question and must create a hypothesis and a test for it. Students should work in groups to create a hypothesis and test for each question. Questions may also be assigned to groups. Have groups conduct their experiment and present their results. One class period can be used to create the experiment and begin data collection. Another class period can be used to finish collecting data and present the results.

Depending on the characteristics of the schoolyard ecosystem, soil and/or water tests may be conducted.

Materials
Student science notebooks
Pencils
Soil test kits, water test kits, or lab probes for nitrogen (nitrites, nitrates, ammonia) and phosphorous
Safety goggles
Safety gloves

Procedure
1. Have students complete headings in their science notebooks.

2. Give students the questions:
   a. Where would we find the greatest amount of nitrate in our schoolyard ecosystem?
   b. Where would we find the greatest amount of phosphorus in our schoolyard ecosystem?

3. Have groups create a hypothesis and test procedure for one or both of the questions above. Have students write these in their science notebooks.

4. Have students identify the independent and dependent variables, the materials they need to test their hypothesis and data tables for collection of information.

5. Have students write a multi-step procedure for testing their hypothesis. It should include at least three essential steps needed to conduct a valid experiment. Prompt students to write experiments that other researchers (students) could clearly follow and successfully complete.

6. Have students conduct the test in their schoolyard ecosystem.

7. Have students create a data table to record findings.

8. Have students use the following questions to write a summary in their science notebook:
    a. Did their data support their hypothesis? Why or why not?
    b. Where was the greatest concentration of the element tested? How would that affect the plant and animal life?
    c. Where was the least concentration of the element tested? How would that affect the plant and animal life?
    d. How have human influences affected their findings?
    e. What other questions can be generated from the data collected?

Wrap up
1. Have students create a presentation of their findings for the rest of the class. This should include at least one of the element cycles (nitrogen, phosphorus) with examples from their schoolyard ecosystem.

Assessment
Refer to *Appendix 3: Scoring Guide for Oral Presentation* on page 215 and *Appendix 5: Scoring Guide for Experimental Design* on page 217.

Extensions
1. Make a class list of questions generated from the data collected by each group. Determine which of these questions are testable and use them to create a hypothesis and an experiment.

2. Design and conduct an experiment on the effects of adding fertilizers to a small site on the schoolyard ecosystem.

3. Design and conduct an experiment to test for carbon.

Lesson 7
End of Chapter Assessment

1. Define the terms atom, element, molecule and compound.

2. List the elements that are essential for life.

3. Give an example of how the geosphere is a reservoir for atoms.

4. What is the chemical process that moves atoms from one sphere to another?
   a. condensation
   b. evaporation
   c. translocation
   d. photosynthesis

Questions 5 through 12

   Match the description with the appropriate abiotic cycle. Answers may be used once, more than once or not at all.
   a. The water cycle
   b. The nitrogen cycle
   c. The carbon cycle
   d. The phosphorus cycle

5. This abiotic cycle has no atmospheric component.

6. This cycle is needed for plants to make amino acids and DNA.

7. Transpiration is a process in plants that is part of this cycle.

8. Bacteria live in a symbiotic relationship with a plant, such as a bean, pea or other legume.

9. Precipitation, runoff and percolation are all processes in this cycle.

10. The largest amount of this element is stored in mineral form.

11. Lightning and bacteria convert a gas into a form plants can use.

12. A large amount of this element is stored as fossil fuels.

13. Give an example of how the use of nitrogen fertilizers affects aquatic ecosystems.

14. Describe how greenhouse gases are being put into the environment and the possible effect their build up may have on the environment.

15. Explain the importance of recycling nitrogen, oxygen and carbon within an ecosystem.

16. High concentrations of lead were found in a wetland area. The watershed for this wetland contains the following: a forested area, a shooting range and small farms. What would the resource manager responsible for the wetland need to do? Write the procedure the resource manager would need to follow and the data he or she would need to collect.

17. What effects might lead have on wetland species?

Lesson 7
End of Chapter Assessment Scoring Guide

1. Define the terms atom, element, molecule and compound.
   Answer:
   a. Atom—the smallest portion of a chemical element that maintains the properties of that element
   b. Element—a particular kind of atom based on the number of protons found in the atom's nucleus
   c. Molecule—a combination of two or more atoms
   d. Compound—molecule that contains at least two different elements
   (4 points)

2. List the elements that are essential for life.
   Answer: Oxygen, Carbon, Hydrogen, Nitrogen, Phosphorus **(2 points)**

3. Give an example of how the geosphere is a reservoir for atoms.
   Answer: The largest reservoir of phosphorus occurs in sedimentary rocks. The geosphere is composed of all the rocks and minerals making up the Earth's land. **(2 points)**

4. What is the chemical process that moves atoms from one sphere to another?
   a. condensation
   b. evaporation
   c. translocation
   d. photosynthesis
   Answer: d **(1 point)**

Questions 5 through 12
   Match the description with the appropriate abiotic cycle. Answers may be used once, more than once or not at all. **(1 point each)**
   a. The water cycle
   b. The nitrogen cycle
   c. The carbon cycle
   d. The phosphorus cycle

5. This abiotic cycle has no atmospheric component. **Answer:** d

6. This cycle is needed for plants to make amino acids and DNA. **Answer:** b

7. Transpiration is a process in plants that is part of this cycle. **Answer:** a

8. Bacteria live in a symbiotic relationship with a plant, such as a bean, pea or other legume. **Answer:** b

9. Precipitation, runoff and percolation are all processes in this cycle. **Answer:** a

10. The largest amount of this element is stored in mineral form. **Answer:** d

11. Lightning and bacteria convert a gas into a form plants can use. **Answer:** b

12. A large amount of this element is stored as fossil fuels. **Answer:** c

13. Give an example of how the use of nitrogen fertilizers affects aquatic ecosystems.
    Answer: Plants need nitrogen, and small amounts of nitrogen fertilizers can increase plant growth leading to more plants. When large amounts of fertilizers run off the land into watersheds, eutrophication can occur. This depletes the oxygen in the water, causing the aquatic ecosystem to collapse. **(2 points)**

14. Describe how greenhouse gases are being put into the environment and the possible effect their build up may have on the environment.
    Answer: Carbon-based gases (greenhouse gases) allow sunlight to pass through but trap heat. This is called the greenhouse effect which is important in creating earth's temperatures. However, these gases are building up at an alarming rate which has scientists concerned about global climate change. **(2 points)**

15. Explain the importance of recycling nitrogen, oxygen and carbon within an ecosystem.
    Answer: Because of gravity and the conservation of matter, the Earth is a closed system. Elements provide the basis for life and are recycled, reused and rearranged. They must move through an ecosystem so that they can be utilized. **(2 points)**

16. High concentrations of lead were found in a wetland area. The watershed for this wetland contains the following: a forested area, a shooting range and small farms. What would the resource manager responsible for the wetland need to do? Write the procedure the resource manager would need to follow and the data he or she would need to collect.
    Answer: The resource manager would need to investigate the watershed for point and non-point source pollution. Some questions the resource manager might ask:
    - Is there lead paint being used on the farms?
    - Is lead shot used at the shooting range?
    - Is there illegal dumping on the forested area?

    Once the source of the lead has been identified, the resource manager could devise a response plan. Options to consider:
    - Identify the hazards lead poses.
    - Identify ways to clean it up and prevent its recurrence.
    - Install lead containment and recycling systems.
    - Inform and educate the public. **(4 points)**

17. What effects might lead have on wetland species?
    Answer: Lead is toxic even in small concentrations. It causes irreparable bone, nerve and muscle damage. Animals exposed to lead may starve to death, become easy prey or pass lead up the food chain where it will kill other animals. **(2 points)**

Lesson 8: Diversity and Disturbance of Biological Communities

Estimated time
(3) 50-minute class periods for activities

Science CLEs

EC.1.B.b. Predict how populations within an ecosystem may change in number and/or structure in response to hypothesized changes in biotic and/or abiotic factors

EC.1.C.b. Predict and explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents)

EC.1.D.a. Predict the impact (beneficial or harmful) a natural or human-caused environmental event (e.g., forest fire, flood, ~~volcanic eruption, avalanche~~, acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on the diversity of different species in an ecosystem

EC.3.C.c. Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of non-native species) can be agents of natural selection

IN.1.A.a. Formulate testable questions and hypotheses

IN.1.B.a. Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., ~~microscopes~~, thermometers, analog and digital meters, computers, ~~spring scales~~, ~~balances~~, metric rulers, ~~graduated cylinders~~)

Vocabulary

Biological community	Biodiversity hotspots
Structure	Conservation opportunity areas
Species richness	Equilibrium model of island biogeography
Relative abundance	Equilibrium point
Species evenness	Succession
Diversity indices	Primary succession
Species diversity	Secondary succession
Biodiversity	Disturbance
Species-area rule	Pioneer
Featured-species management	Early successional community
Community management	Climax community

Objectives

1. Explain how species richness and relative abundance are used to measure and compare communities.

2. Define biodiversity in terms of genes, species and ecosystems.

3. Explain the importance of high biodiversity.

4. Describe how biodiversity is affected by latitude, habitat complexity and area.

5. Explain how immigration and extirpation affect species diversity.

6. Illustrate how populations within a community change following an environmental disturbance.

7. Distinguish between primary and secondary succession.

8. Compare and contrast the adaptations of early and late successional species.

Resource Management Objectives

1. Distinguish between featured-species and community management.

2. Explain the importance of setting back succession to manage prairies.

Essential Questions

1. What is the importance of biodiversity?

2. What causes populations to change?

Teacher Notes

Students should read *Nature Unbound* Chapter 8 before beginning Lesson 8 activities.

Outline of Answers to Objectives

See following page.

Essential Activities

Essential Activity 8.1—Measuring Biodiversity
Essential Activity 8.2—Increasing Biodiversity
Essential Activity 8.3—Thinking Like a Resource Manager

End of Chapter Assessment

Lesson 8 Questions and Answer Key

Summary

- Ecologists use species richness and relative abundance to measure and compare biological communities.
- Biodiversity refers to the variety of genes, species and ecosystems in a given area.
- Biodiversity is affected by latitude, habitat complexity and area.
- The species richness of a community is a balance between immigration and extinction.
- Communities undergo a sequence of predictable changes following a disturbance.
- Early and late successional species have different adaptations.

Outline of Answers to Objectives

1. **Explain how species richness and relative abundance are used to measure and compare communities.** (*Nature Unbound* pp. 98-99)
   a. Species richness is the measurement of the number of species a community contains.
   b. Relative abundance shows how abundant one species is relative to all the others in a community.
   c. Taken together, species richness and relative abundance give an impression of the variety of life that exists within a community.

2. **Define biodiversity in terms of genes, species and ecosystems.** (p. 101)
   a. Biodiversity is made up of three components:
      i. Species diversity—Species richness and relative abundance found in a certain area.
      ii. Genetic diversity—The variety of genotypes found among individuals in a population. High genetic diversity allows a species to adapt to changing environments.
      iii. Ecosystem diversity—The variety of different ecosystems that exist within a larger region such as a landscape or watershed.
   b. Biodiversity is an important yardstick to measure and compare different biological communities. This helps ecologists determine which areas support the greatest number of species, which areas would make good nature preserves, and which areas might provide habitat for endangered species.

3. **Explain the importance of high biodiversity.** (p. 102)
   a. High biodiversity helps stabilize biological communities and helps communities recover from environmental change or human disturbance. Ecologists have shown that ecosystems recover faster from droughts, fires, diseases and other natural disasters if they harbor many species rather than just a few.

4. **Describe how biodiversity is affected by latitude, habitat complexity and area.** (pp. 102-104)
   a. Latitude—For most groups of organisms, species richness increases toward the equator.
   b. Habitat complexity—Biodiversity is higher in complex ecosystems than simple ecosystems. Ecologists reason that more layers of vegetation provide more niches for a greater diversity of species.
   c. Area—As a general rule, large areas harbor more species than small areas (species-area rule).

5. **Explain how immigration and extirpation affect species diversity.** (pp. 106-107)
   a. Species richness is a balancing act between immigration of new species into a community and extirpation of existing species from a community.
   b. As more species move in, the immigration rate will go down because fewer and fewer arrivals will be new species. Also competition between species will increase. Some species will outcompete others leading to competitive exclusion. Thus, as species richness increases, extirpation rates also increase. An equilibrium point is reached—the rate of immigration is balanced by the rate of extirpation.
   c. The immigration rate of a habitat is influenced mainly by its distance from a potential source of immigrants.
   d. Extirpation rates are influenced by the size of a block of habitat. Small "islands" where resources are scarce will have higher extirpation rates than larger "islands" where resources are plentiful.
   e. This is called the equilibrium model of island biogeography, first proposed by MacArthur and Wilson.

6. **Illustrate how populations within a community change following an environmental disturbance.** (pp. 107-108)
   a. After an environmental disturbance, a community will go through a sequence of changes called succession, or the replacement of one biological community by another over time. The populations within these communities also change to reflect the successional stage of the community.

7. **Distinguish between primary and secondary succession.** (p. 108)
   a. Primary succession—This begins on areas without soil, such as bare rock, lava flows and areas scraped lifeless by retreating glaciers.
   b. Secondary succession—This occurs when the preceding community is destroyed but the soil is not.

8. **Compare and contrast the adaptations of early and late successional species.** (pp. 108-109)
   a. Adaptations of early successional species:
      i. Seeds disperse easily and quickly.
      ii. Seeds can remain dormant in the soil for many years.
      iii. Plants germinate, grow and reproduce quickly.
   b. Adaptations of late successional species:
      i. Seeds are relatively large, providing more nutrients.
      ii. Plants grow slower than early successional species.
      iii. Plants allocate more growth to roots and stems to allow them to out-compete early successional species for water, sunlight and nutrients.
      iv. Organisms have adaptations that enhance their ability to compete for scarce resources.

Resource Management Objectives

1. **Distinguish between featured-species and community management.** (p. 105)
   a. Featured-species management focuses on a specific species.
   b. Community management focuses on the entire biological community.

2. **Explain the importance of setting back succession to manage prairies.** (p. 111)
   a. In a prairie community, disturbance maintains the climax community. Therefore periodic disturbance, usually controlled burns, helps maintain the climax prairie community.

Essential Activity 8.1
Measuring Biodiversity

Estimated Time
(1) 50-minute class period

Objectives
Students will be able to:
1. Explain how species richness and relative abundance are used to measure and compare communities.

2. Explain the importance of high biodiversity.

3. Illustrate how populations within a community change following an environmental disturbance.

Teacher Preparation
Have students reference *1.3 Transects—Collecting Data* from their science notebooks and Table 8.2 on page 101 of the student book. Have students use the prior data collected and recorded from three areas in the schoolyard ecosystem as well as conduct sampling of three additional areas to determine and compare species richness, species evenness and biodiversity. Students should reference equations on pages 98-101 of the student book to determine:
- Species richness: the total number of different species in each location
- Species abundance: percentage of abundance of one species relative to all the others in a community
- Biodiversity: Shannon-Weiner Index (species richness and relative abundance in a certain area)

Materials
Student science notebooks
Pencils
Nature Unbound student book
Completed *1.3 Biotic Data—Plants* and *Biotic Data—Animals*
Copies of *8.1 Species Diversity Data Sheet* (one per student)
Scientific calculators

Procedure

1. Have students complete their science notebook headings.

2. Have students work in small groups to determine the species richness, relative abundance and biodiversity for the data tables they created in *Essential Activity 1.3.*

3. Students should transfer the information collected in the tables from *Essential Activity 1.3* to the *8.1 Species Diversity Data Sheet* in order to do the calculations.

4. Have students explain which site is more diverse.
   a. Explanations should include:
      i. claim (statement indicating which ecosystem is more diverse)
      ii. evidence (specific evidence/data showing values that indicate differences in species richness, biodiversity and species evenness)
      iii. reasoning (a statement that links the evidence back to the claim showing why the evidence counts and makes connections to appropriate scientific principles)

5. Have students present their claims to the class. Were they all in agreement? Why or why not?

Wrap up

1. Have students discuss the following:
   a. Why does an ecologist study biodiversity?
   b. How might the diversity indices affect a management plan for an area?
   c. Which site has the highest biodiversity, and why is this important?
   d. What would happen to the diversity indices of the sites sampled if there had been a disturbance such as fire, flooding, etc.?

Assessment

1. Refer to *Appendix 3: Scoring Guide for Oral Presentation* on page 215.

2. See *Scoring Guide for Claims and Evidence* on next page.

Scoring Guide for Claims and Evidence

Component	Level		
	2	1	0
Claim—An assertion or conclusion that answers the original question	Makes an accurate and complete claim	Makes an accurate but incomplete claim	Does not make a claim or makes an inaccurate claim
Evidence—Scientific data that supports the claim Data needs to be appropriate and sufficient to support the claim.	Provides appropriate and sufficient evidence to support claim	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence	Does not provide evidence or only provides inappropriate evidence (evidence that does not support claim)
Reasoning—A justification that links the claim and evidence and shows why the data counts as evidence to support the claim by using appropriate and sufficient scientific principles	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles	Provides reasoning that links the claim and evidence. Repeats the evidence and/or includes some but insufficient scientific principles	Does not provide reasoning or only provides reasoning that does not link evidence to claim

Extensions

1. Have students calculate species richness, species abundance and biodiversity for the data tables created in *Essential Activity 1.1*.

2. Have students sample other areas and calculate the diversity index.

8.1 Species Diversity Data Sheet

Directions: Use the data collected in *1.3 Biotic Data—Plants* and *Biotic Data—Animals* to complete the chart below. Refer to the equations on page 100 of the student book to calculate the Shannon-Wiener diversity index.

Site # _____

Species	Number of Individuals	Proportions (p_i)	$\log_e p_i$	$p_i (\log_e p_i)$
TOTAL				

Essential Activity 8.2
Increasing Biodiversity

Estimated Time
(1) 50-minute class period

Objectives
Students will be able to:
1. Explain how species richness and relative abundance are used to measure and compare communities.

2. Explain the importance of high biodiversity.

3. Describe how biodiversity is affected by latitude, habitat complexity and area.

4. Explain how immigration and extirpation affect species diversity.

5. Illustrate how populations within a community change following an environmental disturbance.

6. Distinguish between primary and secondary succession.

7. Compare and contrast the adaptations of early and late successional species.

Teacher Preparation
Have students work in small groups and reference *8.2 Resource Management Scenarios Sheet*.

Materials
Student science notebooks
Pencils
Nature Unbound student book
Copies of *8.2 Resource Management Scenarios Sheet* (one per group)

Procedure
1. Have students complete their science notebook headings.

2. Provide each group with a copy of *8.2 Resource Management Scenarios Sheet*.

3. Have students read and discuss the scenarios.

4. Have groups refer to Chapter 8 of their student book to answer the scenario questions. Groups should support their claims and evidence by including discussions of the following concepts (and/or other specific information/concepts) from Chapter 8 listed below:
   a. Species richness and relative abundance can be used to measure and compare communities.
   b. High biodiversity is important.
   c. Biodiversity is affected by latitude, habitat complexity and area.
   d. Immigration and extirpation affect species diversity.
   e. Populations within a community change following an environmental disturbance.
   f. There are differences between primary and secondary succession.
   g. Early and late successional species have different adaptations.

Wrap up

1. Have groups share their discussions with the class. Groups should reference specific paragraphs of Chapter 8 to support their claims and evidence.

Assessment

Refer to the *Scoring Guide for Claims and Evidence* in *Essential Activity 8.1*.

8.2 Resource Management Scenarios Sheet

Scenario 1

You are the resource manager for a conservation area. This area is a 1,000-hectare forest located in the Ozarks. All of the trees were cut down about 100 years ago. Since then, the forest has regrown into a climax community, and now all the trees are roughly the same age. To increase the biodiversity of the area, what steps would you take?

Scenario 2

You are the resource manager for a conservation area. On a site inventory, you discover a dry, rocky area on the southwestern slope of a wooded hillside. The area is overgrown with cedars and a few oak trees, but you know at one time this spot was a glade inhabited by grasses, wildflowers and lizards. What steps would you take to change the hillside back into a glade? How would changing the area back into a glade increase the biodiversity of the wooded hillside?

Essential Activity 8.3
Thinking Like a Resource Manager

Estimated Time
(2) 50-minute class periods

Objectives
Students will be able to:
1. Explain the importance of high biodiversity.

2. Illustrate how populations within a community change following an environmental disturbance.

3. Distinguish between primary and secondary succession.

4. Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible effects of human interactions with that ecosystem (e.g., harvesting, pollution, atmospheric changes).

Teacher Preparation
This activity may be done indoors or outdoors. Have students work in the same groups as *Essential Activity 8.2*. Have groups reference their discussion notes from *8.2 Resource Management Scenarios Sheet*.

Have student refer to page 44 of the student book for background information for Scenario 1. Have students refer to page 77 of the student book for background information for Scenario 2.

Materials
Student science notebooks
Pencils
Nature Unbound student book
8.2 Resource Management Scenarios Sheet (one per group)

Procedure

1. Have students complete their science notebook headings.

2. Have groups reference information compiled during *Essential Activity 8.2* and recorded on their *8.2 Resource Management Scenarios Sheet.*

3. Have groups choose either Scenario 1 or Scenario 2 and devise a multi-step plan to restore the stability and/or biodiversity of the specific conservation area ecosystem.

4. Plans must include:
   a. A prediction of how the population(s) within the chosen conservation area ecosystem might have changed in number and/or structure in response to the changes in biotic and/or abiotic factors.
   b. An explanation of how environmental factors may have been agents of natural selection within the chosen conservation area ecosystem.
   c. A prediction of the impact (beneficial or harmful) the natural or human-caused environmental event of the chosen conservation area ecosystem may have had on the diversity in the ecosystem.
   d. A prediction and explanation of how natural or human-caused changes in the chosen conservation area ecosystem might affect other ecosystems due to natural mechanisms.
   e. The steps to restore or manage for the stability and/or biodiversity of the chosen conservation area ecosystem.

Wrap up

1. Have groups prepare and present their plans as resource managers.

Assessment

1. Refer to *Appendix 3: Scoring Guide for Oral Presentation* on page 215.

2. Refer to *Management Plan Scoring Guide* on next page.

Management Plan Scoring Guide

	3 points	2 points	1 points	0 points
A prediction of how the population(s) within the chosen conservation area ecosystem might have changed in number and/or structure in response to the changes in biotic and/or abiotic factors	Complete prediction and description of change to the population in number and structure as a response to a change in the biotic and or abiotic factors\n\nThese factors are described.	Complete prediction and incomplete description\n*or*\nIncomplete prediction and complete description	Incomplete prediction and no description\n*or*\nNo prediction and incomplete description	No prediction or description
An explanation of how environmental factors could have been agents of natural selection within the chosen conservation area ecosystem	A complete explanation of how environmental factors could have been agents of natural selection within the chosen conservation area ecosystem	An incomplete explanation but the environmental factors within the chosen area have been recognized	An incomplete explanation with no environmental factors recognized	No explanation
A prediction of the impact (beneficial or harmful) a natural or human-caused environmental event in the chosen conservation area ecosystem may have had on the diversity in the ecosystem	A complete prediction of the impact and a description of the environmental event that has or may occur in the chosen ecosystem	An incomplete prediction and complete description of the event\n*or*\nComplete prediction and an incomplete description	An incomplete prediction with no description of the impact of the environmental event	No prediction
A prediction and explanation of how natural or human-caused changes in the chosen conservation area ecosystem might affect other ecosystems due to natural mechanisms	Complete prediction and explanation of how natural or human-caused changes in the chosen conservation area ecosystem might affect other ecosystems due to natural mechanisms	Incomplete prediction with an explanation of the natural or human caused changes\n*or*\nComplete prediction with an incomplete explanation	Incomplete prediction with no explanation of the natural or human caused changes	No prediction or explanation
The steps of a plan to restore or manage for the stability and/or biodiversity of the chosen conservation area ecosystem	Steps of the plan follow a logical sequence and timeline to restore biodiversity	Steps of the plan are incomplete, but they follow a time-line	The plan is incomplete. The steps do not follow a timeline. There are only 1 or 2 steps and biodiversity is not restored.	No plan is created

Lesson 8
End of Chapter Assessment

1. Interpret the graph below.
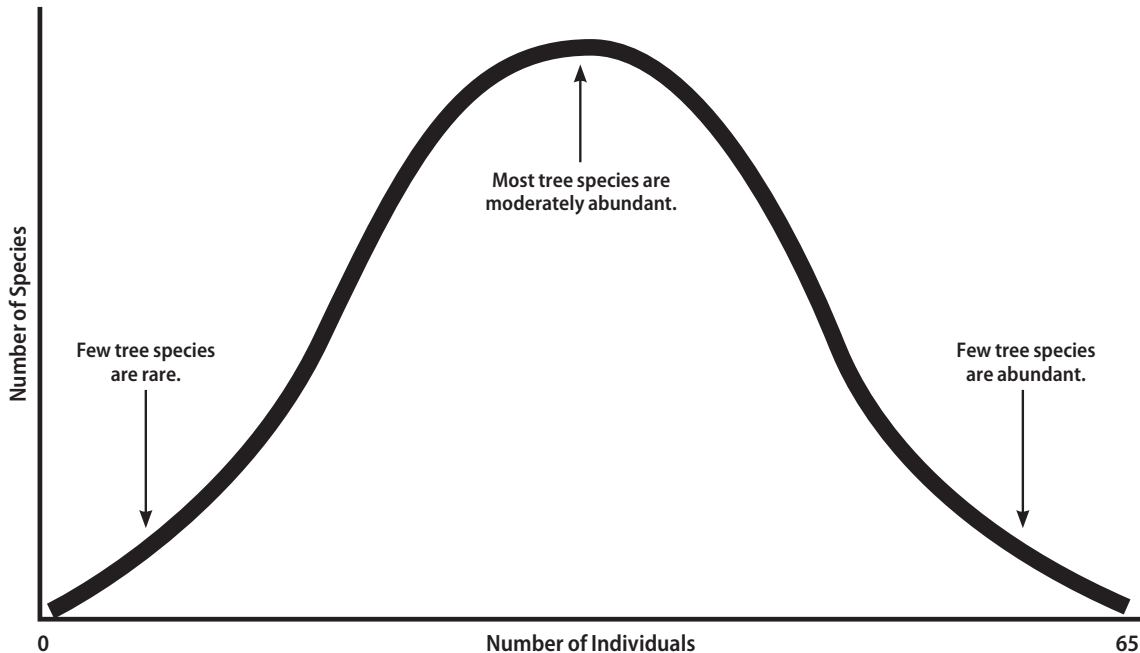
This graph illustrates which of the following?
a. That species increase and decrease
b. The relative abundance of species in a community
c. A bell shaped curve that indicates species health
d. The rate of population growth over time

2. Define biodiversity in terms of genes, species and ecosystem.

3. Which community is more stable—one with high biodiversity or one with low biodiversity? Explain your answer.

4. Which area would be most likely to have the highest biodiversity?
a. A 10-acre forest in North America
b. A 10-acre prairie in North America
c. A 10-acre forest in South America
d. A 2-acre forest in South America

5. Explain how immigration and extirpation affect species diversity.

6. A tornado cuts a path through the Mark Twain National Forest. The trees in the forest are leveled, creating large swaths of open areas. Number the successional changes below in the order in which each would occur in the forest community.
___ Perennial plants and woody vegetation (low shrubs) would appear.
___ Climax vegetation of a mature forest is evident.
___ Early successional species will move in (annual plants).
___ Small trees (high shrubs) would appear.

7. Explain the differences between primary and secondary succession.

8. Describe two adaptations of early successional species.

9. Which of the following describes adaptations of late successional species?
   a. Have adaptations that help them germinate, grow and reproduce quickly
   b. Have adaptations that enhance their ability to compete for scarce resources
   c. Have adaptations that produce multicolored flowers
   d. Have adaptations that enhance their ability to produce high energy carbohydrates

10. Describe one step to consider in a plan to restore biodiversity to an ecosystem.

11. Why is it important to set back succession when managing for a climax prairie community?

Lesson 8
End of Chapter Assessment Scoring Guide

1. Interpret the graph below. (See graph on page 205) This graph illustrates which of the following?
   a. That species increase and decrease
   b. The relative abundance of species in a community
   c. A bell shaped curve that indicates species health
   d. The rate of population growth over time
   Answer: b **(1 point)**

2. Define biodiversity in terms of genes, species and ecosystem.
   Answer:
   • Genetic diversity—Genetic diversity is the variety of genotypes found among individuals in a population. High genetic diversity allows a species to adapt to changing environments.
   • Species diversity—Species diversity refers to the species richness and relative abundance found in a certain area.
   • Ecosystem diversity—Ecosystem diversity refers to the variety of different ecosystems that exist within a larger region such as a landscape or watershed.
   • Biodiversity is an important yardstick to measure and compare different biological communities. This helps ecologists determine which areas support the greatest number of species, which areas would make good nature preserves and which areas might provide habitat for endangered species.
   (4 points)

3. Which community is more stable—one with high biodiversity or one with low biodiversity? Explain your answer.
   Answer: A community with high biodiversity is more stable. High biodiversity helps stabilize biological communities and helps communities recover from environmental change or human disturbance. **(2 points)**

4. Which area would be most likely to have the highest biodiversity?
   a. A 10-acre forest in North America
   b. A 10-acre prairie in North America
   c. A 10-acre forest in South America
   d. A 2-acre forest in South America
   Answer: c **(1 point)**

5. Explain how immigration and extirpation affect species diversity.
   Answer: Species diversity can increase as more species move in (immigrate.) However, over time, as more species move in, the immigration rate will go down because fewer and fewer arrivals will be new species. Also, competition between species will increase. Some species will outcompete others leading to competitive exclusion. Thus, as species richness increases, extirpation rates also increase. An equilibrium point is reached—the rate of immigration is balanced by the rate of extirpation. **(2 points)**

6. A tornado cuts a path through the Mark Twain National Forest. The trees in the forest are leveled, creating large swaths of open areas. Number the successional changes below in the order in which each would occur in the forest community.
   Answer:
   2. Perennial plants and woody vegetation (low shrubs) would appear.
   4. Climax vegetation of a mature forest is evident.
   1. Early successional species will move in (annual plants).
   3. Small trees (high shrubs) would appear.
   (4 points)

7. Explain the differences between primary and secondary succession.
   Answer: Primary succession begins on areas without soil, such as bare rock, lava flows and areas scraped lifeless by retreating glaciers. This is in contrast to secondary succession which occurs when the preceding community was destroyed but the soil is intact. **(2 points)**

8. Describe two adaptations of early successional species.
   Answer:
   Species grow quickly.
   Species reproduce quickly.
   Species produce many small seeds.
   Seeds disperse easily and quickly.
   Seeds can remain dormant in the soil for years.
   (2 points)

9. Which of the following describes adaptations of late successional species?
   a. Have adaptations that help them germinate, grow and reproduce quickly
   b. Have adaptations that enhance their ability to compete for scarce resources
   c. Have adaptations that produce multicolored flowers
   d. Have adaptations that enhance their ability to produce high energy carbohydrates
   Answer: b **(1 point)**

10. Describe one step to consider in a plan to restore biodiversity to an ecosystem.
    Answer should include one of the following steps:
    a. A prediction of how the population(s) within the chosen conservation area ecosystem might have changed in number and/or structure in response to the changes in biotic and/or abiotic factors.
    b. An explanation of how environmental factors could have been agents of natural selection within the chosen conservation area ecosystem.
    c. A prediction of the impact (beneficial or harmful) the natural or human-caused environmental event of the chosen conservation area ecosystem may have had on the diversity in the ecosystem.
    d. A prediction and explanation of how natural or human-caused changes in the chosen conservation area ecosystem might affect other ecosystems due to natural mechanisms.
    e. The steps of a plan to restore or manage for the stability and/or biodiversity of the chosen conservation area ecosystem.
    (2 points)

11. Why is it important to set back succession when managing for a climax prairie community?
    Answer: The tallgrass prairie biome and the eastern deciduous forest biome meet in Missouri. Historically, the "line" between the two was determined by rainfall and fire frequency. Without periodic fires, trees advance into prairies and shade out the grasses. Fire, the disturbance to the natural community that helps maintain the prairie, has been suppressed since European settlement. A resource manager must introduce fire to restore and maintain a climax prairie community, thus setting back succession. **(2 points)**

Lesson 9: Culminating Activity—Researching and Planning Like a Resource Manager

Estimated Time
Minimum of (2) class periods and 1 day for field experience

Science CLEs
EC.1.C.a. Devise a multi-step plan to restore and/or manage for the stability and/or biodiversity of an ecosystem when given a scenario describing the possible adverse effects of human interactions with that ecosystem (e.g., destruction caused by direct harvesting, prescribed burns, harvesting, habitat restoration, poaching, pollution, atmospheric changes)

IN.1.B.a. Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., ~~microscopes~~, thermometers, analog and digital meters, computers, ~~spring scales~~, ~~balances~~, metric rulers, ~~graduated cylinders~~)

IN.1.C.a. Use quantitative and qualitative data as support for reasonable explanations (conclusions)

Objective
1. Devise a multi-step plan to restore the stability and/or biodiversity of an ecosystem when given a scenario describing the possible effects of human interactions with that ecosystem (e.g., harvesting, pollution, atmospheric changes).

Teacher Preparation
Students will research and develop a management plan based on an actual ecosystem within 100 miles of the school or based on an area within or adjacent to the schoolyard ecosystem.

Have students work in groups. Group plans should include formulating testable questions and hypotheses and designing and conducting a valid field experiment. If possible, while students are working at the research site, arrange for a visit by the area manager and/or landowner of the site.

Materials
Student science notebooks
Pencils
Nature Unbound student book
Name, details, coordinates, etc. of a specific ecosystem within 100 miles of the school
    (provided by teacher or researched and decided upon by class)
Tools (decided upon by groups to accomplish specific research)

Procedure

Pre-Field Experience

1. Have groups research the area's history, ecosystem components, management practices in effect (if any), etc.

2. Have groups utilize Google Earth, GIS/Arcview or other mapping technology to create a map of the area.

3. Groups should assess the stability and/or biodiversity of the ecosystem.

4. Before the field experience, students must decide:
    a. What data is needed to help with their plan
    b. What tools are needed to collect the necessary data

Field Experience and Post-Field Experience

1. Have groups collect pertinent data and record observations and questions they have while collecting data.

2. If possible while at the site, have groups visit with the area manager, landowner, etc.

3. From data collected, groups should devise a multi-step resource management plan to restore the stability and/or biodiversity of the specific area ecosystem.

4. Management plans must include:
    a. Overview—Explanation and description of the area to be managed.
        *   Identify the habitat type.
        *   Use collected data to give the area a biodiversity index.
        *   Use data and record problems and/or potential problems or opportunities, for example, invasive species, endangered species, etc.
    b. Status of Area—Outline the situation or status. (Why is this area considered for a management plan?)
    c. Goal(s)—What are the goals for the management plan? (What do you want to accomplish?)
        *   Identify at least 3 goals.
    d. Action Items/Strategies—How will the goal-specific actions be accomplished (be put into place)? What is going to be done, and how long will it take? (Many management plans take years to accomplish.)
        *   Identify at least 1 action item/strategy for each goal.
    e. Assessment of Management Plan—How will the success of the management plan be assessed? Does the assessment match original goals? How would a multi-year plan be assessed? How would a multi-step assessment be used?
    f. Appendix
        *   Data collected to create the management plan
    *   References
        *   All other information that supports the management plan

5. Groups should prepare a presentation of their resource management plan to the class. They should also include an evaluation of their plan. How could they have made it better? Was there other data that could have been collected? Would other tools have made the task easier?

Assessment

1. Refer to *Appendix 3: Scoring Guide for Oral Presentation* on page 215.

2. Refer to *Scoring Guide for Management Plan* on next page.

Scoring Guide for Management Plan

	2 points	1 points	0 points
Overview of management plan	Overview is complete. Description of area includes habitat type and a biodiversity index. A problem/opportunity has been identified.	Overview is incomplete.	No overview
Status of area	Complete description of status of the area	Incomplete description	No description
Goals	3 or more goals are described.	1-2 goals are described.	0-1 goal is described
Action items/strategies	Each goal has an action item.	Not all goals have an action item, or they are incomplete.	No action items
Assessment plan	There is a plan for how the success of the management plan will be determined.	The assessment plan is incomplete.	There is no plan.
Appendix	The data collected about the area is included, and references are included.	Either data or references are missing.	No data or references

Appendix 1: Scoring Guide for Data Sheets

Score	Description	Criteria
4 points	Exceeds expectations	All data sheets are complete. Comments and descriptions are included for each type of plant and animal sign. Common names and/or scientific names are used.
3 points	Meets expectations	All data sheets are complete. Comments or descriptions are included for each type of plant and animal sign. Some plants are identified.
2 points	Not yet within expectations	Some factors are missing from the abiotic data sheet (no more than two). Few comments or descriptions are included. No identification of species is included.
1 point	Below expectations	Many factors are missing from abiotic data sheet (3 or more). No comments or descriptions are included.
NS	Not scorable	Data sheets are unreadable. No information was collected.

Appendix 2: Checklist for Notebooks

Notebook Element	Present	Not Present
Each new entry is added to the Table of Contents with title and page number.		
Date is included in each heading.		
Time is included in each heading.		
Location is included in each heading.		
Page number is included on each page.		
Each entry has a title and focus.		
Abiotic data is entered.		
Temperature is added.		
Weather conditions are included.		
Soil moisture (if applicable) is added.		
Observations are detailed and clear.		
Sketches (if applicable) are entered and labeled.		
Data table (if applicable) is labeled and accurate.		
Data gathered is easy to read and complete.		
Open ended question is generated.		
Question can be investigated.		
A claim is made, and there is evidence to support that claim.		

Appendix 3: Scoring Guide for Oral Presentation

Name_____ Date _____

Title/Topic_____

_____ Total Score/Grade

	4 Points	3 Points	2 Points	1 Point
Content/ Organization	• Clear purpose, subject • Accurate content • Sufficient support • Major ideas clearly summarized	• Some success defining purpose, subject • May contain minor inaccuracies • Some supporting details • Major ideas summarized but need refinement	• Attempts to define purpose, subject • Contains some inaccuracies • Weak support • Major ideas summarized but unclear	• Purpose/subject not defined • Many inaccuracies • Weak or no supporting details • Major ideas unclear or not summarized
Delivery	• Relaxed, self-confident • Consistent eye contact • Maintains appropriate volume and inflection	• Remains calm in spite of minor mistakes • Fairly consistent eye contact • Satisfactory volume and inflection	• Some tension • Inconsistent eye contact • Unsatisfactory volume with little or no inflection	• Nervous tension obvious • Little eye contact • Low volume and/ or monotonous tone

Comments: _____

_____

_____

Appendix 4: Scoring Guide for Science Writing

Scoring Guide			
Criteria	**3**	**2**	**1**
The student will write an informative report with supporting details on the topic and use problem solving to locate information.	The paper has an effective beginning, middle and end with a title. It clearly addresses the topic and provides specific and relevant details/examples with a clear controlling idea.	The paper has a beginning, middle and end. It generally addresses the topic but may contain some details that are not relevant. It contains a general sense of direction, but may lack focus.	The paper lacks evidence of a beginning, middle and/or end. It attempts to address the topic, but lacks development and is difficult to follow and/or lacks focus.
The student will use correct grammar, punctuation, and spelling. The student will use correct indentation and complete sentences.	The paper contains few errors in grammar, punctuation and/or spelling. It generally uses complete sentences.	The paper contains errors in grammar, punctuation, and/or spelling that may be distracting to the reader. It contains some incomplete sentences that may be distracting to the reader.	The paper contains repeated errors in grammar, punctuation and/or spelling that may be distracting to the reader. It includes incomplete sentences that are distracting to the reader.

From DESE:
http://www.dese.mo.gov/divimprove/curriculum/ModelCurriculum/writingreason/summ_assess_scoring_guide.htm

Appendix 5: Scoring Guide for Experimental Design

Testable Question
Maximum Number of Points: 1

1 Point
> Student correctly provides any reasonable testable question or statement of problem that:
> - Identifies what will be tested or measured
> - Will generate quantifiable data
> - Has a control or comparison inherent in the question
>
> Exemplary responses might take these appropriate forms:
> - Does (independent variable) affect (dependent variable)?
> - How does (independent variable) affect (dependent variable)?
> - Will (independent variable) affect (dependent variable)?

0 Point
> The student does not correctly provide a reasonable testable question or statement of problem that meets the criteria listed above.

Hypothesis
Maximum number of Points: 1

1 Point
> The student correctly provides any reasonable hypothesis based on the testable question or statement of a problem that predicts an effect, or the lack of effect, of the independent variable on the dependent variable.
>
> Exemplary responses take these appropriate forms:
> - If (independent variable) (description of change in independent variable), then (dependent variable) (description of event).
> - As the (independent variable) (description of changes), the (dependent variable) (description of observed changes in dependent variables).
> - The (qualitative/quantitative change in independent variable) of (independent variable), the (quantitative change in dependent variable).
>
> *NOTE*: The "if, then" format does not have to be used in the student response in order for the student to earn full credit.

0 Point
> The student does not provide a reasonable hypothesis based on the testable question or statement of a problem that predicts an effect, or the lack of effect, of the independent variable on the dependent variable.

Independent Variable
Maximum number of Points: 1

1 Point
> The student correctly identifies the independent variable for this investigation. The variable that is purposely manipulated (changed) by the experimenter is the independent variable. The independent variable is the factor believed to cause a change in the dependent variable.

0 Point
> The student does not correctly identify the independent variable for this investigation.

Dependent Variable
Maximum number of Points: 1

1 Point
> The student correctly identifies the dependent variable for this investigation. The variable that changes in response to the independent variable and is observed (collected as data) is the dependent variable.

0 Point
> The student does not correctly identify the dependent variable for this investigation.

Constants
Maximum number of Points: 1

1 Point
> The student correctly identifies why it is important to keep some conditions constant during an investigation. Constants are factors that remain the same and have fixed values.
> Any one of the following is acceptable:
> - Their purpose is to isolate the factor (independent variable) that can affect the results.
> - Their purpose is to make a fair comparison between the independent and dependent variables possible.
> - Constants are important because other variables could affect the results of the investigation.
>
> *OR*
> - Any valid statement explaining why constants are important including examples related to this investigation

0 Point
> The student does not correctly identify why it is important to hold some conditions constant during an investigation.

Identification of Constants
Maximum number of Points: 2

2 Points
> The student correctly identifies two constants for this investigation. Constants are factors that remain the same and have fixed values. Their purpose is to isolate the factor (independent variable) that can affect the results.

1 Point
> The student correctly identifies one factor that should be kept constant for this investigation.

0 Point
> The student does not correctly identify any factors that should be kept constant for this investigation.

Equipment
Maximum number of Points: 3

3 Points
>The student correctly identifies three pieces of equipment for this investigation.

2 Points
>The student correctly identifies two pieces of equipment for this investigation.

1 Point
>The student correctly identifies one piece of equipment for this investigation.

0 Point
>The student does not correctly identify any pieces of equipment for this investigation.

Graphing
Maximum number of Points: 4

4 Points
>The student correctly includes all four elements on the graph.
>One point for each of the following:
>- Appropriate title: a statement of the relationship between the independent and dependent variables or a statement of what is being tested
>- Both axes correctly labeled, with units, if appropriate
>- Appropriate number scales labeled along each axis: numbers written on the grid lines, numbers that allow all data to be plotted, consistently scaled
>- All data points correctly plotted

3 Points
>The student correctly provides three of the four elements on the graph.

2 Points
>The student correctly provides two of the four elements on the graph.

1 Point
>The student correctly provides one of the four elements on the graph.

0 Point
>The student does not correctly provide any of the four elements on the graph.

Adapted from *2008 Biology Performance Event Released Form Rubric*
http://www.dese.mo.gov/divimprove/assess/documents/Biology_Performance_Event_Released_Rubric.pdf

E00190

NATURE UNBOUND: THE IMPACT OF ECOLOGY ON MISSOURI AND THE WORLD